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ON THE GENERAL RELATIONS OF VARIABLE STAR PHENOMENA,

By S. C. CHANDLER.

At a recent meeting of the National Academy of Sciences I invited attention to the various relations which seem to be more or less clearly exhibited among the phenomena pertaining to the variable stars. Some of them were pointed out for the first time; others are not new, but it seemed useful to examine them afresh, in the light of the evidence of to-day, in order to revise our notions of their probability, as well as to see what significance they may have when the mutual connections of all are considered. The basis of the examination was the catalogue of variable stars published in 1888. Such a review of the subject does not appear to be superfluous. Although the data at hand are not yet sufficient to lead to numerous or very certain conclusions, we are justified in beginning that coordination of facts which is likely to put us in the way of recognizing the laws governing the phenomena. It is needless to say that until such a foundation for a true science of the variable stars is laid, speculation as to causes is entirely premature.

In undertaking a comparison of the various phenomena of the variable stars, the most natural investigation to start with pertains to that set of relations which spring from the fact of periodicity; namely, the coordination of the lengths of the periods with the numbers of the variables, with their color, with their range of fluctuation, with the forms of their light-curves, and with the irregularities of their periods and of their light-variations. The limited number of the objects to be compared, and our ignorance of the elements mentioned for many of them, greatly restrict the certainty of our conclusions, but, from what follows, the existence of certain of these relations appears beyond doubt. I proceed to take them up in their order.

The deviation from uniformity in the numbers of the variables with respect to their periods long ago appeared; at first obscurely, afterwards with increasing emphasis as the data waxed in volume, until it can no longer be regarded as a chance-relation merely, but as having a real connection with the nature of things. The basis of this inference is the following table, containing three classifications; the first, by **Schönfeld** in 1863, with the 71 periods then known; the second, with the 101 certainly determined periods of his catalogue of 1875; the last, with the 160 periods of my catalogue.

Limits of period	1863	1875	1888
Under 20 days	7	13	25
Between 20 and 50 “	3	2	5
“ 50 “ 80 “	4	3	3
“ 80 “ 110 “	1	0	1
“ 110 “ 140 “	0	1	4
“ 140 “ 170 “	4	5	5
“ 170 “ 200 “	3	3	6
“ 200 “ 230 “	2	8	12
“ 230 “ 260 “	5	5	7
“ 260 “ 290 “	4	11	15
“ 290 “ 320 “	8	8	16
“ 320 “ 350 “	8	14	17
“ 350 “ 380 “	9	11	17
“ 380 “ 410 “	4	7	9
“ 410 “ 440 “	4	4	8
“ 440 “ 470 “	3	2	4
“ 470 “ 500 “	2	2	2
over 500 “		2	4

The excess of short periods is still striking, even if we exclude the nine stars of the *Algol*-type in the first group. The maximum for the long-period variables lies at about 320 days, as appears from a chart constructed from these numbers. Such a distribution as is here indicated cannot be due to any circumstance of the method of discovery. On the contrary, we can distinctly perceive a reason for a deficiency in the discovery of variables with periods of about a year. The annually recurring similar phases of brightness of such stars makes a condition which enables them to elude detection for a long series of years together; as, for instance, where their maxima occur near conjunction with the sun. The number of variables discovered, directly or indirectly, by observation in or near the meridian is from this cause doubtless greatly curtailed. We may, therefore, safely infer that the tendency to excess of number near the annual period is actually greater than appears.

The fact, that a large proportion of variables are more or less red, early attracted notice, and the existence of a real connection of some sort between color and variability has long been commonly accepted. While our knowledge of its nature is obscure, it may be formulated, perhaps, in this proposition; that those stars whose chemical constitution manifests itself to us by redness of their light are especially inclined to oscillations in brightness. To proceed further, and examine the relation between the degree of redness and the length of the period, was an obvious step, attempted by SCHMIDT and the writer, independently and at about the same time, many years ago; but the material by which it was sought to establish the relation was unsatisfactory. A series of observations which I published in No. 186 of this Journal remedies somewhat the defect of our knowledge in this regard. I extract from that paper the following tabulation, giving the average periods and redness, in groups, of the stars included in my investigation, adding in the last two groups some of SCHMIDT's observations of a few short-period variables, reduced to the same scale of redness.

Number of Stars	Average Period	Average Redness	Number of Stars	Average Period	Average Redness
4	$517^{\mathrm{d}}.6$	7.3	4	$307^{\mathrm{d}}.9$	4.2
4	449.8	8.1	3	299.0	2.9
4	423.4	6.8	4	285.2	3.0
4	408.4	4.7	4	276.1	3.9
4	383.6	5.5	4	269.4	3.4
4	376.1	3.9	4	252.7	2.2
4	364.6	4.7	4	220.7	2.3
4	355.6	5.1	4	203.2	2.2
4	342.5	3.6	4	178.7	2.0
4	333.5	3.8	5	153.0	1.6
4	325.2	3.1	5	49.7	1.6
4	322.0	3.1	5	11.8	1.8
4	315.6	3.5	5	4.3	1.4

Referring to the paper in question for more particular remarks, I will simply repeat the expression, in its concluding paragraph, of the opinion that "it may be regarded as established that the redness of the variable stars is, in general, a function of the lengths of their periods of light-variation. The redder the tint, the longer the period. It is needless to point out the significance of this association of two sets of phenomena, relating in all probability, one to the dynamics of the star, the other to the chemical condition of its photosphere. Its importance as a touchstone for hypotheses in regard to the causes of stellar variability is evident."

Let us now ascertain whether any systematic relation obtains between the range of variation and the period. Unfortunately, we are ignorant of the mean brightness at minimum in the case of more than one-half of the periodical variables, being able only to fix the superior limit at minimum by means of the known limit of the optical power of the telescopes employed in observing them. In many of these instances, however, we can make an approximate estimate of the mean minimum magnitude, from a consideration of the forms of the light-curves indicated by the observations near the time of disappearance in the telescope. But to avoid, as much as possible, confusion and uncertainty in our conclusions, it seems best to separate the evidence into two classes, comprising respectively that which is complete and reasonably precise, and that which is only approximate and partly supposititious; and then, by comparison, see if the testimony of the two correspond. Accordingly, employing only those stars which have both maximum and minimum epochs assigned in my catalogue, (13th and 14th columns), taking for each the mean range between maximum and minimum brightness from the 11th and 12th columns, arranging in order of periods and grouping, — we have the results in the table below, under the head I. Again, doing the same for the remainder of the periodical stars in the catalogue, we have the results under the head II; only in this case the average values of the range require some assumption, for many of the stars, as to the mean amount of the descent below the superior limit of minimum magnitude assigned in column 12. From careful estimate, I believe it is safe to infer that this quantity is not so great as a unit of magnitude, and is more probably nearer half a unit. The latter is the value adopted in the table.

I			II		
No.	Period	Range	No.	Period	Range
4	$461^{\mathrm{d}}.7$	3.75	4	$602^{\mathrm{d}}.4$	4.48
4	422.9	4.00	4	435.5	4.93
4	383.1	5.25	4	386.7	5.65
			4	374.6	5.17
			4	361.5	4.95
4	345.4	4.28	4	350.8	4.90
			4	338.8	4.20
			4	326.2	4.30
			4	321.6	4.62
4	312.8	4.18	4	315.4	5.07
			4	306.2	4.45
			4	290.6	5.10
			4	283.8	4.95
5	269.8	4.62	4	270.1	5.02
			4	246.8	4.95
			4	229.1	2.97
4	215.5	3.92	4	212.0	4.19
4	186.7	4.67	4	182.5	3.50
4	136.1	2.87	4	142.3	4.07
4	57.5	1.15	3	41.1	1.13
4	22.7	1.35			
4	8.8	1.15			
4	7.0	1.37			
5	5.0	1.04			

It needs but a glance at a chart constructed from these tables to show: first, that the evidence of the two classes of independent data is in satisfactory accord; secondly, that a distinct dependence of the range of fluctuation upon the duration of the period is, at least, probable; thirdly, that this relation, whatever its true law, is manifestly not one of proportionality of range to period. Even if we leave out of account the short-period variables, say those under 100 days, these conclusions still hold. If a continuous line be introduced in the chart to indicate the general course of the data of observation, the range seems to increase up to periods of about a year, afterwards to diminish slightly; but this last feature is not at all certain.

We now come to the relations between the forms of the light-curves and the periods. Astronomers have long been aware of the existence of an analogy in the light-curves which may be defined thus: — by far the larger portion of the periodical variables increase in light more rapidly than they diminish, the only considerable class of exceptions to this general rule being the *Algol*-variables. So far as I know, the subject has not been pursued further, probably chiefly for want of proper material as a basis for the examination. Thus, in Schönfeld's catalogue of 1875, the maximum and minimum epochs are both assigned for only thirty-one stars. In my catalogue I have been able to increase this number to sixty-three; which is sufficient to warrant taking up the inquiry. The most suitable element for investigation in this direction is the ratio of the time of increase to that of decrease. If, therefore, we compute this quantity from the data of the catalogue, for the only class of stars for which it is practicable to do so, — namely, those embraced under the heading "I" in the foregoing paragraph, — and form averages of groups as there indicated, we have the following results:

No.	Period	Ratio of Increase to Decrease
	d	
4	461.7	1.055
4	422.9	0.835
4	383.1	0.804
4	345.4	0.536
4	312.8	0.852
5	269.8	0.866
4	215.5	0.897
4	186.7	0.990
4	136.1	1.020
4	57.5	0.636
4	22.7	0.609
4	8.8	0.758
4	7.0	0.633
5	5.0	0.656

Unity, of course, corresponds to equal times of increase and decrease, values less than unity to greater rapidity of increase than of decrease, and *vice versa*. The interpretation of the results will be more perspicuous from a diagram formed from them. The first feature which strikes the eye is the strong suggestion of discontinuity in the relation exhibited, as between the variables of long and short period; and this appears quite as forcibly from an inspection of the ratios of the individual stars, as from the mean values here given. The average ratio for stars with periods less than 100 days, is about 0.65; between 100 and 200 days, it is slightly in excess of unity; it then declines as the periods lengthen, at first gradually, but in the neighborhood of a year with extraordinary suddenness, recovering as quickly, until it again exceeds unity in the group of extremely long periods. That the exceptionally small value for stars of ten or twelve months period is not accidental, is apparent by the accordance of all the individual ratios within this limit, viz:

o Ceti	0.49
T Arietis	0.61
R Geminorum	0.41
R Canis minoris	0.51
S Coronae	0.50
R Aquilae	0.64

I cannot forbear the expression of regret that fuller means are not at hand for more completely establishing, or of disproving, this most curious relation, and that of the preceding paragraph. The defect can only be supplied by some of the larger telescopes, taking up resolutely and systematically the determination of the minima of the fainter variables; an appeal for which research was made, and the means supplied to facilitate it, in No. 183 of this Journal.

The last topic proposed in the second paragraph is one upon which our knowledge is not yet fully enough developed to permit of a general examination here. I have now in hand a series of investigations upon the numerical laws of the perturbations in the periods of the variables; a portion of them have already been published, the rest will appear in due time. The discussion of these inequalities, from the point of view of the present paper, must await the completion of this work. Meanwhile one remark on the subject may be ventured here. There seems to be a significant difference between the types of irregularities by which the long-period and the short-period variables are affected. Broadly characterized, this difference is that, in the former case, the irregularities are in general periodic in their nature, and seem to be present in a large majority of the stars of the class; while in the latter, they are secular, or at least operate in cycles covering incomparably more numerous single periods of the star, and are, besides, exceptional, their existence being perceptible in proportionally rare instances. It would lead me too far to particularize the evidence on which this impression has been formed, and the subject must be dismissed until it can be taken up to better advantage, with the results of the pending calculations completely before us.

A comparative review of the previous results suggests several interesting inferences. In particular, — noting, in the first table, the absence of stars with periods between 90 and 120 days (the only one in the group, *U Geminorum*, being in every respect of an exceptional type); in the second the colorlessness of stars below the same limit, in contrast with the decided red tints prevailing above it; in the third and fourth the sharp contrast, below and above the same point, in the average range of fluctuation, and in the character of the light-curves, respectively; and finally, the apparently typical differences in the inequalities of period, alluded to in the previous paragraph; it is hard to resist a strong conviction that the underlying phenomena are essentially heterogeneous, and that the designation commonly employed, for convenience of arbitrary classification, of long-period and short-period variables, marks a real distinction in the fundamental nature of the objects themselves, and that the variations of light in the two cases arise from causes totally diverse. If, with more abundant means than we now possess, this proposition is confirmed, a natural classification will result, by which we can distinguish real differences of type, as sharply as we now do the stars of the *Algol*-type from the other short-period variables.

The conclusion here drawn may perhaps be regarded by some as obvious, or already so highly probable that this statement of the grounds for it is unnecessary. This does not seem to be at all so to me, however, but the hypothesis appears to be a reasonable one for future trial.

The inquiry as to the existence of peculiarities in the aggregation of the variables is a tempting path, the exploration of which may be of some little use if we keep away from its pitfalls. But the range of our present outlook must be greatly extended before deductions can be worth much. The distribution of the known variables over the face of the sky is far too likely to be fortuitous, even if all could be used; and yet a considerable proportion of the whole number, scant as that is, must be excluded from consideration, to avoid vitiating results by subjective errors. Our knowledge has been advanced very largely by indirect causes, and not in any such manner as a systematic and impartial search of the whole firmament would have done. A glance at the accompanying table, which contains some additions to the data of the catalogue, to bring it to date, will show the impetus given by the asteroid-search since the middle of the century, and by the construction of the *Durchmusterung* and the *Uranometria Argentina*.

Interval	No.
1572 – 1604	4
1670 – 1686	3
1782 – 1795	8
1809 – 1811	2
1820 – 1824	1
1825 – 1829	4
1830 – 1834	3
1835 – 1839	0
1840 – 1844	1
1845 – 1849	15
1850 – 1854	18
1855 – 1859	29
1860 – 1864	30
1865 – 1869	17
1870 – 1874	33
1875 – 1879	14
1880 – 1884	28
1885 – 1889	20

Discoverer	No.
Gould	23
Hind	21
Argelander	17
Schmidt	17
Peters	17
Pogson	14
Baxendell	14
Schönfeld	9
Sawyer	7
Espin	6
Harding	5
Dunér	5
Chandler	5
Auwers	4
Winnecke	4
Chacornac	4
Hencke	4
Goodricke, Pigott, Krueger, Palisa and Gore, each	3
Seven observers, each	2
Various observers, each	1

For the brighter variables, the labors of Gould have within a few years placed the southern on an equality, at least, with the northern sky, although the latter has been scanned by many observers for more than a century; but the thoroughness of the gleaning of the two hemispheres for the telescopic stars, on the contrary, has been as widely different as could well be. Certain minor causes also operate towards a factitious grouping and to mask any real laws of arrangement that may exist. However, I have thought it worth while to study the subject somewhat, constructing for the purpose two stereographic hemispherical projections containing all the known variables, distinguished by convenient symbols for the various classes. The projections are on a plane perpendicular to the galaxy, whose north pole, successively investigated by W. Herschel, Argelander, Houzeau and Gould, was taken for 1855 at R.A. = $12^h\ 40^m$, Decl. = +27° 30′. The median line of the galaxy is the equator of the projection, and the galactic longitudes are counted, in the accompanying tabulations, from the ascending node of the galaxy upon the terrestrial equator, i.e., from RA = $18^h\ 40^m$.

For the following classifications we must exclude that region of the sky below the mean southern horizon of the generality of observers. This region, roughly described, embraces longitudes 210° to 330° south of the galaxy, and a somewhat smaller average range for the belt between the galaxy and 30° north. We also drop all the stars discovered by recognized finders of asteroids, lying along a narrow belt near the ecliptic.

The following table gives, under the head I, in groups of galactic polar distance 20° broad, the distribution of the variables between 330° and 210° longitude, not including what may be called, for brevity, the asteroid class, or the short-period variables, belonging mostly to the brighter magnitudes; and, by the side of these numbers, the ratios of density, R′, relative to that of the middle group (80° — 100°), which is taken as unity. Under the head II are given, for all longitudes from 0° to 360°, the numbers of the short-period variables except those of the *Algol*-type; and by the side the similar ratios of density, *R″*, to that of their middle group. Under the head III are given the corresponding ratios of density, *D′*, according to Seeliger, of the stars of the *Durchmusterung*, for stars in the limits of magnitude $6^{\rm M}.5 - 9^{\rm M}.5$, and *D″* for those brighter than $6^{\rm M}.5$.

Galactic N.P.D	I		II		III	
	No.	R′	No.	R″	D′	D″
0° – 20°	1	0.17	0	0.00	0.35	0.55
20 – 40	14	0.87	1	0.13	0.36	0.57
40 – 60	16	0.65	1	0.08	0.45	0.64
60 – 80	19	0.63	3	0.20	0.68	0.79
80 – 100	32	1.00	16	1.00	1.00	1.00
100 – 120	20	0.66	6	0.40	0.77	0.91
120 – 140	7	0.28	0	0.00	0.47	0.57
140 – 160	5	0.31	0	0.00	0.41	0.43
160 – 180	2	0.36	0	0.00	–	–

Comparing R' with D', and making allowance for the uncertainty of the former due to the small numbers involved, there appears to be no noticeable difference in the character of the two series of ratios; from which fact we may infer that there is no manifest tendency to a different law of distribution among the telescopic long-period variables, from that which prevails for the stars of our system in general, in their aggregation with respect to the Milky Way. If, however, we compare R'' with D'', the tendency to aggregation near the plane of the galaxy is quite striking. It will be singular indeed if this should prove to be merely accidental. On the charts this phenomenon exhibits itself in the shape of a stream of short-period variables, not in the course of Dr. GOULD's belt of bright stars, but far more nearly in that of the Milky Way, adhering closely to the southern branch of the latter in its bifurcation near *Cygnus*.

A classification in longitude leads to the following table, the enumeration being made separately for the two hemispheres. Two maxima are here more or less certainly marked in both the northern and southern groups, at 30° and 165° longitude, corresponding, respectively, to points in the sky near β *Cygni* and α *Orionis*. It should be noted that longitudes from 200° to 330° cover portions of the sky where our knowledge is defective south of the galaxy, but far less so north of it.

Cambridge, 1889 *April*.

Galactic Long.	Galactic N.P.D. 0° – 90°	Galactic N.P.D. 90° – 180°
° – °		
0 – 30	18	8
30 – 60	16	12
60 – 90	9	10
90 – 120	5	5
120 – 150	4	4
150 – 180	13	9
180 – 210	5	2
210 – 240	5	4
240 – 270	3	5
270 – 300	4	4
300 – 330	5	4
330 – 360	9	5

There is no inequality in the aggregation of the stars in general, in different portions of the galaxy, in a faint degree approximating to this irregularity in longitude among the variables. Still I will hazard no opinion on its reality. Indeed, for the reasons assigned above, we must view with distrust all inferences as to the distribution of the variables, based on our present fragmentary information. The number of known stars must be increased manifold, and the growth must be far more the result of systematic search for them embracing the whole sky, and not dependent as in the past on haphazard, — before the subject can be examined to any advantage. With the present slow rate of advance the epoch for this lies far in the future.

FILAR-MICROMETER OBSERVATIONS OF COMET *b* 1889 (*BARNARD*, *March 31*),

MADE WITH THE 12-INCH EQUATORIAL,

BY E. E. BARNARD, ASTRONOMER OF THE LICK OBSERVATORY.

The following observations are in continuation of those previously sent.

The comet was seen April 11, but was so excessively faint, from moonlight and haze, that it is thought best not to include the observation in this list.

On the 15th and 22d it was very faint in the haze.

The tail was very difficult to measure on all the dates, but could be traced for 10′ or 15′. The nucleus was about 13ᴹ, and perfectly stellar.

It is now cloudy here, and, if the unfavorable weather lasts for a week, the comet will not be visible again, unless it be observable after passing the sun.

1889 Mt. Hamilton M.T.	⁎	No. Comp.	☄ — ⁎ $\Delta\alpha$	☄ — ⁎ $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
d h m s			m s	′ ″	h m s	° ′ ″		
April 3 8 9 24	1	10 , 7	—1 46.50	— 6 43.3	5 18 26.94	+16 0 30.9	9.604	0.605
9 1 59	2	12 , 7	—1 31.96	— 0 4.1	5 18 25.37	+16 0 27.4	9.658	0.646
5 9 17 45	1	8 , 8	—3 15.54	—11 3.9	5 16 57.87	+15 56 10.3	9.674	0.666
15 8 35 48	3	10 , 6	+0 9.21	+ 4 23.3	5 11 30.65	+15 36 23.3	9.673	0.668
16 7 58 39	3	17 , 5	—0 15.05	+ 2 30.7	5 11 6.38	+15 34 30.7	9.657	0.649
17 8 15 52	3	16 . 7	—0 38.81	+ 0 32.9	5 10 42.61	+15 32 32.8	9.619	0.653
18 8 3 58	3	12 , 7	—1 0.50	— 1 17.9	5 10 20.92	+15 30 42.0	9.663	0.655
19 8 1 29	3	12 , 7	—1 21.32	— 3 10.5	5 10 0.09	+15 28 49.4	9.664	0.655
21 8 5 8	4	16 , 6	—0 28.14	— 2 10.4	5 9 21.96	+15 25 7.1	9.675	0.676
22 8 14 41	4	16 , 6	—0 45.39	— 4 1.2	5 9 4.71	+15 23 16.3	9.677	0.678
24 8 13 53	4	10 . 6	—1 16.84	— 7 40.1	5 8 33.26	+15 19 37.5	9.680	0.683
8 56 48	5	8 . 5	—1 45.71	+ 2 2.6	5 8 32.94	+15 19 32.9	9.688	0.711
25 8 42 57	5	8 , 6	—1 59.35	+ 0 15.7	5 8 19.29	+15 17 16.0	9.687	0.708
26 8 19 33	5	10 , 6	—2 12.35	— 1 31.8	5 8 6.27	+15 15 58.5	9.684	0.693
28 8 27 50	5	6 , 4	—2 35.89	— 5 12.6	5 7 42.71	+15 12 17.7	9.687	0.705
29 8 19 58	5	8 , 5	—2 46.21	— 7 5.6	5 7 31.57	+15 10 21.7	9.686	0.704

Mean Places for 1889.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	5 20 14.30	{ −0.86 { −0.89	+16 7 19.5	{ −5.3 { −5.3	Weisse's Bessel V, 519 (mean)
2	5 19 58.19	−0.86	+16 0 35.8	−5.3	Compared with Weisse's Bessel V, 519
3	5 11 22.51	{ −1.07 { −1.10	+15 32 5.5	{ −5.5 { −5.6	Compared with Weisse's Bessel V, 316
4	5 9 51.21	−1.11	+15 27 23.0	−5.5	Compared with *3
5	5 10 19.78	{ −1.13 { −2.00	+15 17 35.7	{ −5.4 { −5.4	Compared with *4

DETERMINATION OF COMPARISON-STARS.

Stars	No. Comp.	Δα	Δδ
		m s	′ ″
*2 — W.B., V, 519	15 , 5	−0 16.11	−6 43.7
*3 — W.B., V, 346	6 , 3	−2 59.19	+0 42.0
*4 — *3	10 , 4	−1 31.30	−4 42.5
*5 — *4	8 , 5	+0 28.57	−9 47.3

Mt. Hamilton, 1889 *April* 23.

POSITION-ANGLE OF TAIL.

	d h	° ′	
April	3 9	80 0	3 observations
	17 9	75 0	3 "
	18 9	78 3	3 "
	21 9	75 5	3 "

OBSERVATIONS OF COMET *b* 1889 (*BARNARD, March 31*),

MADE WITH THE 15-INCH EQUATORIAL OF THE HARVARD COLLEGE OBSERVATORY,

BY O. C. WENDELL, ASSISTANT.

[Communicated by Professor EDWARD C. PICKERING, Director.]

1889 Greenwich M.T.	*	No. Comp.	☄ — *		☄'s apparent		log pΔ	
			Δα	Δδ	α	δ	for α	for δ
d h m s			m s	′ ″	h m s	° ′ ″		
April 2 13 38 28	1	5	−0 55.25	− 4 16.1	5 19 18.13	+16 2 58.1	9.614	0.695
6 13 16 24	2	5	+0 24.99	− 6 16.5	5 16 24.41	+15 54 32.6	9.612	0.694
19 13 18 42	3	5	−4 18.97	− 2 20.8	5 10 1.55	+15 28 57.3	9.649	0.733
23 13 11 28	4	5	−1 56.84	+13 12.8	5 8 49.42	+15 21 36.4	9.652	0.738

Mean Places for 1889.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	5 20 14.22	−0.84	+16 7 19.4	−5.2	Weisse's Bessel V, 519–522
2	5 16 0.34	−0.92	+16 0 54.5	−5.4	" " V, 392, 393
3	5 14 21.61	−1.09	+15 31 23.6	−5.5	" " V, 346
4	5 10 47.38	−1.12	+15 8 29.1	−5.5	" " V, 240

ELEMENTS AND EPHEMERIS OF COMET *b* 1889 (*BARNARD, March 31*),

BY W. W. CAMPBELL.

From the mean of two Lick observations March 31, Vienna April 8, and Ann Arbor April 20, I have computed the following elements and ephemeris of Comet *b* 1889.

$$T = \text{Greenwich M.T. June } 7^{d}.6547$$

$$\left.\begin{aligned} \omega &= 234^\circ\ 55'\ 54'' \\ \Omega &= 310\ \ 51\ \ 44 \\ i &= 163\ \ 53\ \ 19 \end{aligned}\right\}\ \text{Ecliptic and Mean Equinox 1889.0}$$

$$\log q = 0.35437$$

Obs.-Comp.

$$\cos\beta'\,\Delta\lambda' = +4''.1$$

$$\Delta\beta' = -2\ .4$$

Ann Arbor, 1888 *April* 26.

EPHEMERIS FOR GREENWICH MEAN TIME.

1889	α	δ	log Δ	log r	Br.
	h m s	° ′			
April 30.5	5 7 25	+15 9.1	0.4803	0.3623	0.77
May 4.5	6 53	15 1.8	0.4872	0.3607	
8.5	6 34	14 54.4	0.4931	0.3594	
12.5	6 26	46.9	0.4982	0.3582	
16.5	6 24	39.0	0.5025	0.3571	
20.5	5 6 30	+14 30.9	0.5061	0.3562	0.70

[The brightness at the date of discovery is the unit employed.]

OBSERVATIONS OF COMET *b* 1889 (*BARNARD, March 31*),

MADE WITH THE 12-¼INCH EQUATORIAL OF THE DETROIT OBSERVATORY,

BY W. W. CAMPBELL.

1889 Greenwich M.T.	*	No. Comp.	☄ — *		☄'s apparent		log $p\Delta$	
			$\Delta\alpha$	$\Delta\delta$	α	δ	for α	for δ
d h m s			m s	′ ″	h m s	° ′ ″		
April 20 14 21 49	3	6	+6 21.68	—0 5.6	5 9 41.28	+15 27 5.9	9.654	0.741
22 14 10 25	3	9	+5 45.84	—3 45.3	5 9 5.13	+15 23 26.2	9.653	0.740

Mean Place for 1889.0 of Comparison-Star.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
3	5 3 20.73	—1.13 —1.14	+15 27 17.2	—5.7	Newcomb 247

OBSERVATIONS OF COMET 1888 III,

MADE AT THE HAVERFORD COLLEGE OBSERVATORY,

BY F. P. LEAVENWORTH.

1888 Haverford M.T.	*	No. Comp.	☄ — *		☄'s apparent		log $p\Delta$	
			$\Delta\alpha$	$\Delta\delta$	α	δ	for α	for δ
d h m s			m s	′ ″	h m s	° ′ ″		
Sept. 24 7 35 8	1	2	—0 23.88	—10 55.4	15 9 19.28	+18 58 59.6	9.655	0.665
29 7 54 5	2	2	+0 16.85	— 7 24.5	15 27 25.29	+15 26 50.9	9.584	0.700
Oct. 3 7 56 23	3	4	—3 46.44	— 5 32.0	15 40 31.90	+12 48 36.7	9.602	0.714
8 8 23 49	4	2	+1 52.88	— 4 29.1				

Mean Places for 1888.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place.	Authority
	h m s	s	° ′ ″	″	
1	15 9 43.12	+0.04	+19 9 46.0	+9.0	Weisse's Bessel XV, 171
2	15 27 8.22	+0.22	+15 34 6.7	+8.7	Weisse's Bessel XV, 570
3	15 44 18.08	+0.26	+12 54 0.0	+8.7	Schjellerup 5602

The observations were made with a square-bar micrometer. The comet was very faint during the whole series of observations.

OBSERVATIONS OF COMETS,

MADE AT THE U.S. NAVAL OBSERVATORY, WITH THE 9.6-INCH EQUATORIAL.

BY PROF. E. FRISBY.

[Communicated by the Superintendent.]

1889 Wash. M.T.	*	No. Comp.	☄ — *		☄'s apparent		log $p\Delta$	
			$\Delta\alpha$	$\Delta\delta$	α	δ	for α	for δ
				COMET *b* 1889				
d h m s			m s	′ ″	h m s	° ′ ″		
May 1 8 43 55.3	1	2 , 1	+1 16.35	+3 59.6	5 7 12.92	+15 7 45.4	9.677	*n*0.737
				COMET 1888 V.				
May 1 10 21 58.6	2	10 , 3	—3 22.16	—5 20.8	9 31 40.42	+37 41 6.7	9.665	0.261

Both comets extremely faint, and observations uncertain.

Mean Places for 1889.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	5 5 57.53	−0.96	+15 3 51.4	−5.6	Weisse's Bessel (1) V, 52
2	9 35 2.80	+0.08	+37 46 21.5	+6.0	Weisse's Bessel (2) IX, 693

EPHEMERIS OF VARIABLES OF THE *ALGOL*-TYPE.

Approximate Greenwich M.T., 1889.

For remarks and comparison-stars see Vol. VII, p. 187 foll. Also, it should be noted that the times for *Y Cygni* are extremely uncertain, probably by several hours; see Vol. VIII, p. 130.

	May			May			June			June			July	
	d	h		d	h		d	h		d	h		d	h
U Cephei	15	13	*U* Ophiuchi	26	14	*U* Ophiuchi	6	11	*U* Cephei	19	11	δ Librae	1	8
U Ophiuchi	15	16	*Y* Cygni	26	18	*Y* Cygni	7	18	Algol	19	14	*U* Ophiuchi	1	15
Y Cygni	16	6	δ Librae	27	11	*Y* Cygni	9	6	δ Librae	19	17	*Y* Cygni	1	18
U Ophiuchi	16	12	*U* Ophiuchi	27	11	*U* Cephei	9	11	*Y* Cygni	19	18	*U* Cor. Bor.	2	11
R Canis Maj.	17	9	*Y* Cygni	28	6	*U* Ophiuchi	9	20	*U* Ophiuchi	19	21	*U* Ophiuchi	2	11
Y Cygni	17	18	*Y* Cygni	29	18	δ Librae	10	10	*U* Ophiuchi	20	18	*Y* Cygni	3	6
R Canis Maj.	18	12	*U* Cephei	30	12	*U* Ophiuchi	10	16	*Y* Cygni	21	6	δ Librae	3	16
U Cor. Bor.	18	14	*U* Ophiuchi	30	18	*Y* Cygni	10	18	*U* Ophiuchi	21	14	Algol	3	22
Y Cygni	19	6	*Y* Cygni	31	6	*U* Ophiuchi	11	12	*Y* Cygni	22	18	*U* Cephei	4	10
U Ophiuchi	19	21	*U* Ophiuchi	31	15	*U* Cor. Bor.	11	18	*Y* Cygni	24	6	*Y* Cygni	4	18
δ Librae	20	11				*Y* Cygni	12	6	δ Librae	24	9	*U* Ophiuchi	5	20
U Cephei	20	13		June		δ Librae	12	18	*U* Cephei	24	10	*Y* Cygni	6	6
U Ophiuchi	20	17	*U* Cor. Bor.	1	9	*Y* Cygni	13	18	*U* Cor. Bor.	25	13	*U* Ophiuchi	6	16
Y Cygni	20	18	*U* Ophiuchi	1	11	*U* Cephei	14	11	*Y* Cygni	25	18	Algol	6	18
U Ophiuchi	21	13	*Y* Cygni	1	18	*U* Ophiuchi	14	21	*U* Ophiuchi	25	19	*U* Ophiuchi	7	12
Y Cygni	22	6	*Y* Cygni	3	6	*Y* Cygni	15	6	*U* Ophiuchi	26	14	*Y* Cygni	7	18
U Ophiuchi	22	9	δ Librae	3	10	*U* Ophiuchi	15	17	δ Librae	26	17	*Y* Cygni	9	6
Y Cygni	23	18	*U* Cephei	4	12	*U* Ophiuchi	16	13	*Y* Cygni	27	6	*U* Cephei	9	9
Y Cygni	25	6	*Y* Cygni	4	18	Algol	16	17	*U* Ophiuchi	27	11	Algol	9	15
R Canis Maj.	25	8	*U* Ophiuchi	4	19	*Y* Cygni	16	18	*Y* Cygni	28	18	δ Librae	10	16
U Cor. Bor.	25	11	*U* Cor. Bor.	4	20	δ Librae	17	9	*U* Cephei	29	10	*Y* Cygni	10	18
U Cephei	25	12	*U* Ophiuchi	5	15	*Y* Cygni	18	6	*Y* Cygni	30	6	*U* Ophiuchi	10	21
U Ophiuchi	25	19	*Y* Cygni	6	6	*U* Cor. Bor.	18	15	*U* Ophiuchi	30	19			
R Canis Maj.	26	11												

CORRIGENDUM TO THE ELEMENTS OF *X CYGNI*.

BY PAUL S. YENDELL.

Owing to an error of transcription, which escaped detection until after the work had been published, the date of Principal Epoch of this star, given on page 177 of Volume VIII of this Journal, is too early by six hours, and should read: 1886, Oct. 10^d 12^h $11^m.8$, C.M.T. $\pm 52^m.3$. The error, having occurred before computing the ephemeris by the new elements, pervades the entire set of residuals in the columns $_{\mathrm{O}}\overset{Y}{-}{}_{\mathrm{C}}$, to which a correction of $-0^d.25$ should be applied.

Dorchester, Mass., 1889 *May* 4.

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ON THE MASSES OF *MERCURY*, *VENUS* AND THE *EARTH*, AND ON THE SOLAR PARALLAX,

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It is comparatively easy to determine the mass of any planet which is attended by a satellite, but in the case of those which have none, the problem is far more difficult. Among the first attempts to solve it were those of Euler, about 1771, and La Grange, in 1782. The latter geometer deduced a hypothetical relation between the densities of the planets and their distances from the sun, and by combining the densities so obtained with the observed diameters, he found for the mass of *Mercury*, 1 : 2 025 810; for that of *Venus*, 1 : 278 777; and for that of *Mars*, 1 : 1 846 082. Since then the satellites of *Mars* have been discovered; and for determining the masses of *Mercury* and *Venus* the perturbations produced by these planets in the motions of other bodies of the solar system have long been employed.

The history of the attempts to determine the masses of *Mercury* and *Venus* through the law of gravitation may be outlined as follows: In 1841, in the course of his elaborate investigation of the comet which bears his name, Encke deduced some very discordant values of the mass of *Mercury* from its action upon the comet. Since Encke's death the investigations of the comet's motion have been continued, first by Von Asten, and after the death of that astronomer, by Backlund, but without any decisive result as to the mass of *Mercury*; Von Asten's value of that element, found from his discussion of all the observations made upon the comet between the years 1818 and 1868, being 1 : 7 636 400; while Backlund found that the observations from 1871 to 1881, which include the near approach of the comet to *Mercury* in August 1878, cannot be satisfied by Von Asten's mass, but indicate a much larger one, namely, 1 : 2 668 700. Since 1842, Rothman, LeVerrier, Tisserand and Newcomb have derived values of the mass of *Mercury* from the perturbations which it produces in the motions of *Venus* and the *Earth*, but each of these values rests upon a comparatively small amount of data. As to *Venus*, the first computation of its mass was made by LaGrange in 1779, from the precession of the equinoxes, and since then it has been computed by many other astronomers from the perturbations, both periodic and secular, which it produces in the motions of *Mercury* the *Earth*, and *Mars*.

There are in existence not less than fourteen determinations of the mass of *Mercury*, and not less than nineteen determinations of the mass of *Venus*; but the separate values differ largely among themselves, and it is impossible to deduce any trustworthy means from them. A re-discussion of the original data seems the only satisfactory course, and that is the object of the present paper.

To facilitate the discussion of the motions of the nodes of *Mercury* and *Venus*, let

Ω = longitude of the planet's ascending node,
Ω_0 = approximate value of Ω, such that

$$\Omega = \Omega_0 + \Delta\Omega$$

m = mass of the planet,
m_0 = approximate value of m, such that

$$m = m_0(1+r)$$

i = inclination of the planet's orbit to the plane of the ecliptic,
t = time in Julian years of $365\frac{1}{4}$ days, counted from a specified epoch,
$d\lambda\odot$ = correction to the assumed value of the sun's longitude,
$d\beta\odot$ = correction to the assumed value of the sun's latitude,
di = correction to the assumed value of i,
δp and δq = certain coefficients whose numerical values are given by LeVerrier in the *Annales* of the Paris Observatory, Tome II, pp. 100–102.

Further, let symbols relating to the different planets be distinguished by accents and Roman numerals, in the usual way, those relating to *Mercury* being without accent, while those which relate to *Venus* have one accent, those which relate to the *Earth* two accents, and so on to *Neptune*, symbols relating to which will be distinguished by the Roman numeral $^{\text{VII}}$.

In order to make use of Prof. Newcomb's investigation of the longitude of the node of *Mercury*, let us put

$$\Omega = \Omega_0 + \Delta\Omega \tag{1}$$

where the value of Ω_0 is that given by LE VERRIER for the epoch 1850.0, in his tables of *Mercury* (*Annales*, T. V, p. 107), namely,

$$\Omega_0 = 46^\circ\, 33'\, 8''.75 + 42''.643\, t + 0''.000\,083\,5\, t^2 \qquad (2)$$

From a discussion of 23 transits of *Mercury*, occurring between the years 1677 and 1881, NEWCOMB found for the epoch 1820.0 (*Astronomical Papers of the American Ephemeris*, Vol. I. p. 460),

$$N = N_0 + N't = -0''.16 \pm 0''.18 + (0''.28 \pm 0''.42)t$$

Whence, for the epoch 1850.0

$$N = -0''.16 \pm 0''.18 + (0''.28 \pm 0''.42)\,\frac{1850-1820}{100} + (0''.28 \pm 0''.42)t = -0''.076 \pm 0''.220 + (0''.28 \pm 0''.42)t$$

NEWCOMB wrote

$$N = (\delta\theta - \delta l')\sin i$$

but, as $\delta l'$ can not be evalued, when the unit of time is changed from a century to a year this may be regarded as equivalent to

$$\Delta\Omega = \frac{N_0}{\sin i} + \frac{N't}{100 \sin i}$$

which, with $i = 7^\circ\, 0'\, 7''.7$, and the above numerical value of N, gives

$$\Delta\Omega = -0''.623 \pm 1''.805 + (0''.023 \pm 0''.034)t \qquad (3)$$

By substituting (2) and (3) in (1), we obtain definitively for *Mercury*

$$\left.\begin{aligned}\Omega = 46^\circ\, 33'\, 8''.13 \pm 1''.80 + (42''.666 \pm 0''.034)t\\ +0''.000\,083\,5\, t^2\end{aligned}\right\} \quad (4)$$

where t is counted in Julian years of $365\frac{1}{4}$ days, from 1850.0, Paris mean time.

Passing next to *Venus*, ENCKE found from the transit of 1761 (*Der Venusdurchgang* von 1769, pp. 105–107)

Epoch, 1761, June 5, $17^h\, 30^m$ Paris mean time.

Longitude of sun	75° 35′ 49″.6
Latitude of sun	+0 .6
Inclination of *Venus*' orbit	3 23 26 .

$$\Omega' = 74^\circ\, 31'\, 54''.46 + d\lambda\odot - 16.882\, d\beta\odot - 10.919\, d\rho + 0.313\, di'$$

And from the transit of 1769

Epoch, 1769, June 3, $10^h\, 10^m$ Paris mean time.

Longitude of sun	73° 27′ 13″.8
Latitude of sun	0 .0
Inclination of *Venus*' orbit	3 23 26 .

$$\Omega' = 74^\circ\, 36'\, 8''.60 + d\lambda\odot - 16.882\, d\beta\odot + 19.451\, d\rho - 0.339\, di'$$

In order to reduce these results to conformity with the positions of the sun given by the *Tables du Soleil* of HANSEN and OLUFSEN, and to the inclination of the orbit of *Venus* given by HILL's tables of that planet; we take from the latter work, introduction, pp. 2 and 23.

	Transit of 1761	Transit of 1769
	° ′ ″	° ′ ″
Longitude of sun	75 35 52.05	73 27 14.25
Latitude of sun	+0.53	+0.04
i'	3 23 31.64	3 23 31.94

Whence, by comparison with ENCKE's results, and from HILL's tables of *Venus*,

	Transit of 1761	Transit of 1769
	″	″
$d\lambda\odot$	+2.45	+0.45
$d\beta\odot$	—0.07	+0.04
di'	+5.64	+5.94
Perturbations of ♀ in latitude	+0.060	+0.084

	° ′ ″	° ′ ″
ENCKE's observed Ω'	74 31 54.46	74 36 8.60
Correction for $d\lambda\odot$	+2.45	+0.45
" " $d\beta\odot$	+1.182	—0.675
" " di'	+1.765	—2.014
" " perturbations	+1.013	+1.418
Corrected Ω'	74 32 00.87	74 36 07.78

The provisional expression for the longitude of the node of *Venus*, employed by HILL in the construction of his tables of that planet, was

$$\Omega' = 75^\circ\, 19'\, 52''.3 + 32''.2931\, t + 0''.000\,151\, t^2.$$

where t is reckoned in Julian years from the epoch 1850.0. To this, from the meridian observations made at Greenwich, Paris, and Washington during the years 1836 to 1871, he found the correction (*Tables of Venus*, introduction, p. 36),

$$\Delta\Omega' = \frac{w}{\sin i} = +\frac{0''.12}{0.05918} = +2''.028$$

which belongs to the epoch 1855 Jan. 0.0 Washington mean time. Whence, for that epoch

$$\Omega' = 75^\circ\, 22'\, 35''.78$$

From the 1475 photographs of the last transit of *Venus*, reduced by the U.S. Transit of Venus Commission, we have for the epoch 1882 Dec. $6^d\, 5^h\, 0^m$ Greenwich mean time,

$$\Omega' = 75^\circ\, 37'\, 33''.911 + d\lambda\odot - 16.868\, d\beta\odot - 0.321\, di'$$

This result already depends upon the position of the sun given in the *Tables du Soleil* of HANSEN and OLUFSEN, and it requires correction only for the perturbations of *Venus* in latitude. According to HILL's tables of *Venus*, these perturbations amount to $+0''.046$, and the corrected result is therefore

$$\Omega' = 75^\circ\, 37'\, 34''.69$$

From HILL's tables of *Venus*, introduction, p. 2, we have

$$\Omega' = 75^\circ\, 19'\, 53''.10 + 32''.5150\, t + 0''.000\,151\, t^2$$

where

$$\begin{aligned} t &= (\text{Date in Washington mean time}) - 1850.0\\ &= (\text{Date in Greenwich mean time}) - 1850.000\,586\end{aligned}$$

Computing the values of Ω' for the dates of observation by this expression, and collecting our observed results, we have

Julian Date	Computed Ω'	Observed Ω'	C—O
	° ′ ″	° ′ ″	″
1761.398 967	74 31 54.49	74 32 0.87	—6.38
1769.392 654	74 36 14.20	74 36 7.78	+6.42
1854.966 363	75 22 35.66	75 22 35.78	—0.12
1882.897 900	75 37 44.01	75 37 34.69	+9.32

In order to form the observation-equations for the determination of the corrected expression for Ω', let

$$\left.\begin{array}{l} 0 = 75^\circ\,19'\,53''.10 + x + (32''.5150 + y)t + 0''.000\,151\,t^2 \\ \quad -(\text{Observed } \text{☊}' \text{ at the time } t) \end{array}\right\} \quad (5)$$

and then, by putting C for the computed, and O for the corresponding observed value of ☊′, we shall have

$$0 = (\mathrm{C{-}O}) + x + ty$$

The scale of the Julian dates given above is such that 1849.967 042 corresponds to 1850.0 Washington mean time. Bearing that in mind, the following observation-equations result from the values of (C—O):

$$\begin{array}{llr} 0 = -6''.38 + x - 88.568\,y & \text{Weight} & 1 \\ 0 = +6.42 + x - 80.574\,y & \text{"} & 1 \\ 0 = -0.12 + x + 4.999\,y & \text{"} & 1 \\ 0 = +9.32 + x + 32.931\,y & \text{"} & 4 \end{array}$$

The probable error of the observed right ascension of *Venus* was ±0″.470 in 1761, ±0″.196 in 1769, and only ±0″.038 in 1882. Therefore, according to theory the weight of the last observation-equation should be more than 150 times that of either of the first two. Nevertheless, on account of the possible existence of constant errors, it has been thought prudent to give it a weight of only four.

Having regard to the adopted weights, the normal equations are

$$\left.\begin{array}{l} 0 = +\ \ 37''.200 + \ \ 7.000\,x - \ \ 32.419\,y \\ 0 = +1274.847 - 32.419 \ \ + 18\,699.253 \end{array}\right\} \quad (6)$$

and the general solution is

$$x = -\,0.144\,013\,468\,P - 0.000\,249\,677\,Q$$
$$y = -\,0.000\,249\,677\,P - 0.000\,053\,911\,Q$$

in which

$$P = +37''.200 \qquad Q = +1274''.847$$

From the general solution

$$x = -5''.675\,601 \quad \pm 1''.973$$
$$y = -0''.078\,016\,2 \quad \pm 0''.038\,2$$

with which values the residuals in the normal equations are respectively 0″.0000 and —0″.0004, while those in the weighted observation-equations are respectively —5″.146, +7″.030, —6″.186 and +2″.151.

If it is desired to use only the data afforded by transits of *Venus*, we may take ½(1761+1769) and 1882. In that way $d\rho$, the unknown correction to the adopted value of the sun's semi-diameter, is sensibly eliminated from the observations of 1761 and 1769, and our observation-equations become

$$0 = +0''.02 + x - 84.571\,y$$
$$0 = +9''.32 + x + 32.931\,y$$

Whence

$$x = -6''.714 \qquad y = -0.''079\,147$$

The difference between this result, and that from the normal equations (6), is less than the probable error of either.

Reverting to the values of x and y yielded by the equations (6), and substituting them in (5), we obtain definitively, for *Venus*

$$\left.\begin{array}{l} \text{☊}' = 75^\circ\,19'\,47''.42 \ \pm 1.''97 + (32''.4370 \pm 0''.0382)t \\ \qquad\qquad\qquad\qquad + 0''.000\,151\,t^2 \end{array}\right\} \quad (7)$$

which belongs to the epoch 1850.0 Washington mean time.

If we put with LeVerrier (*Annales*, T. II, p. 26)

$$p = \tan i \ \sin \text{☊}$$
$$q = \tan i \ \cos \text{☊}$$

then, regarding all the quantities as variable, and differentiating

$$dp = \frac{\sin \text{☊}}{\cos^2 i}\,di + \tan i \ \cos \text{☊}\,.\,d\text{☊}$$

$$dq = \frac{\cos \text{☊}}{\cos^2 i}\,di - \tan i \ \sin \text{☊}\,.\,d\text{☊}$$

whence, by eliminating di, we find for the theoretical motion of the node on the fixed ecliptic

$$d\text{☊} = \cot i \ \cos \text{☊}\,.\,dp - \cot i \ \sin \text{☊}\,.\,dq$$

To find the theoretical motion on the movable ecliptic, it is only necessary to substitute $dp - dp''$, and $dq - dq''$, for dp and dq. In that way we obtain for *Mercury* and *Venus*.

$$d\text{☊} \ = \cot i \cos \text{☊}\,(dp - dp'') - \cot i \sin \text{☊}\,(dq - dq'') \quad (8)$$
$$d\text{☊}' = \cot i' \cos \text{☊}'(dp' - dp'') - \cot i' \sin \text{☊}'(dq' - dq'') \quad (9)$$

From equations (4) and (7), and from LeVerrier's tables of *Mercury*, and Hill's tables of *Venus*, we have for the epoch 1850.0

$$\begin{array}{ll} \text{☊} \ = 46^\circ\,33'\ \ 8''.15 & i \ = 7^\circ\ \ 0'\ \ 7''.71 \\ \text{☊}' = 75\ \ 19\ \ 47.42 & i' = 3\ \ 23\ \ 35.01 \end{array}$$

By the substitution of these values, together with the values of dp, dp', dp'', dq, dq', and dq'', given in the *Annales* of the Paris Observatory (T. II, pp. 100–101), equations (8) and (9) become

$$\begin{array}{rl} \dfrac{d\text{☊}}{dt} = & -7''.60689 - 0''.06590r \ \ - 1''.10214\,r' \ \ - 0''.92346\,r'' \\ & \qquad\quad - 0\ \ .11238r''' - 2\ \ .28353r^{\mathrm{IV}} - 0\ \ .11704r^{\mathrm{V}} \\ & \qquad\qquad\qquad\qquad\qquad\qquad\quad - 0\ \ .00184r^{\mathrm{VI}} \end{array}$$

$$(10)$$

$$\begin{array}{rl} \dfrac{d\text{☊}'}{dt} = & -17''.36793 + 0''.11193r \ \ - 5''.03855r' \ \ - 6''.71749r'' \\ & \qquad\quad - 0''.22172r''' - 5\ \ .22275r^{\mathrm{IV}} - 0\ \ .27355r^{\mathrm{V}} \\ & \qquad\qquad\qquad\qquad\qquad\qquad\quad - 0\ \ .00418r^{\mathrm{VI}} \end{array}$$

Putting ς' for the general precession, the observation-equations for determining the masses of *Mercury*, *Venus*, and the *Earth* will be of the form

$$0 = \text{theoretical}\ \frac{d\text{☊}}{dt} + \varsigma' - \text{observed}\ \frac{d\text{☊}}{dt} \quad (11)$$

As the masses of all the planets outside the *Earth's* orbit are here regarded as known, the numerical values of their rs must be substituted in the observation-equations. To find them, we have the relation

$$m = m_0(1 + r)$$

where m_0 is the value employed in the observation-equations for the mass of any planet, or in other words, it is the value employed by LeVerrier in forming the quantities dp, dq, etc., and m is the adopted mass of the same planet. The numerical values of $1 \div m_0$, $1 \div m$ and r are given for each planet in Table I.

TABLE 1.

Planet	$1 \div m_0$ LE VERRIER	$1 \div m$ Adopted	Factor r
Mercury	3 000 000	Indeterminate	
Venus	401 847	"	
Earth	354 936	"	
Mars	2 680 337	3 093 500.	—0.133 558
Jupiter	1 050	1 047.55	+0.002 339
Saturn	3 512	3 501.6	+0.002 970
Uranus	24 000	22 600.	+0.061 947
Neptune	14 400	18 780.	—0.233 227

Taking the observed values of the motions of the nodes from equations (4) and (7), the theoretical values from the equations (10), and the factors for the corrections of the masses from Table 1, the formation of the absolute terms of the observation-equations will be as follows:

	Mercury ″	*Venus* ″
Provisional motion of node	— 7.606 89	—17.367 93
Correction for mass of *Mars*	+ 0.015 01	+ 0.029 61
" " *Jupiter*	— 0.005 34	— 0.012 21
" " *Saturn*	— 0.000 35	— 0.000 81
General precession	+50.237 19	+50.237 19
Theoretical $\frac{d\Omega}{dt}$	+42.639 62	+32.885 85
Observed $\frac{d\Omega}{dt}$	+42.666 0	+32.437 0
(C—O) = Absolute term	— 0.026 4	+ 0.448 9

The observation-equations are therefore (12)

$$0 = -0''.0659r - 4''.1021r' - 0''.9235r'' - 0''.0261 \pm 0''.034$$
$$0 = +0\,.1119r - 5\,.0386r' - 6\,.7175r'' + 0\,.4489 \pm 0\,.038$$

whence, leaving r'' indeterminate,

$$r = +28.951\,626\,r'' - 2.495\,943 \quad \pm 0.427$$
$$r' = -\;0.690\,234\,r'' + 0.033\,661 \quad \pm 0.005\,75$$

If we assume $r'' = +0.066\,631$, then

$$r = -0.566\,867 \quad \pm 0.427$$
$$r' = -0.012\,330 \quad \pm 0.005\,75$$

In the *Annales* of the Paris Observatory, T. VI, pp. 286 and 307, LE VERRIER has given four equations which may be used for determining the masses of *Mercury*, *Venus* and the *Earth*. They are derived respectively from the secular motions of the perihelion, eccentricity, inclination, and node of *Mars*; and after multiplication by 100, they are as follows:

$$\begin{array}{rrrrrl} +0''.14r & +\;4''.66r' & +16''.36r'' & +130''.6r^{\mathrm{IV}} & -2''.353 & = 0 \\ +0.08 & +\;0.69 & +\;2.06 & +\;18.2 & -1.115 & = 0 \\ -0.10 & +12.22 & +\;0.03 & -\;13.11 & +0.565 & = 0 \\ -0.69 & -25.60 & -\;6.82 & -\;37.15 & -0.577 & = 0 \end{array} \tag{13}$$

Regarding r, r' and r'' as unknown, the normal equations are

$$\left.\begin{array}{rrrrrl} +\;0''.5121r & +\;17''.1496r' & +\;7''.1580r'' & +\;46''.6845r^{\mathrm{IV}} & -\;0''.0770 & = 0 \\ +17.1496 & +826.8801 & +252.6176 & +1411.9898 & +\;9.9411 & = 0 \\ +\;7.1580 & +252.6176 & +318.4065 & +2427.0777 & -36.8399 & = 0 \end{array}\right\} \tag{14}$$

and the general solution is

$$\begin{array}{rlll} r = & -7.084\,439\,P & +0.129\,718\,Q & +0.056\,347\,7\,R \\ 10r' = & +1.297\,176 & -0.039\,714 & +0.002\,347\,2 \\ 100r'' = & +5.634\,770 & +0.023\,472 & -0.459\,359\,4 \end{array}$$

in which

$$P = +\;46.6845r^{\mathrm{IV}} - 0.0770$$
$$Q = +1411.9898 \quad +\;9.9411$$
$$R = +2427.0777 \quad -36.8399$$

By substituting the value of r^{IV} from Table 1, these quantities become

$$P = +0.0321 \quad Q = +13.2423 \quad R = -31.1654$$

and then, from the general solution

$$r = -0.265\,744 \quad \pm 1.511$$
$$r' = -0.055\,742 \quad \pm 0.035\,76$$
$$r'' = +0.148\,078 \quad \pm 0.038\,47$$

With these values of the rs, the residuals in the normal equations (14), are

$$+0''.000\,001 \quad +0''.000\,055 \quad -0''.000\,008$$

the residuals in the observation-equations (13), are

$$+0''.0779 \quad -0''.8272 \quad -0''.1159 \quad -0''.0634$$

and the probable error of any one of the observation-equations (13), is $\pm 0''.5675$.

We have next to deal with the following group of equations:

$$\begin{array}{rrrrl} 0''.00r & +29''.5\;r' & +225''.3\;r'' & -18''.59 & = 0 \\ -27.39 & -46.33 & -\;51.59 & -18.02 & = 0 \\ +14.3 & +25.5 & +\;27.7 & +\;1.7 & = 0 \\ +\;7.8 & +\;9.2 & +\;15.3 & +\;3.7 & = 0 \\ -\;0.53 & +24.6 & +\;32.8 & -\;1.86 & = 0 \\ -\;1.24 & +40.4 & +\;54.0 & -\;3.28 & = 0 \\ +\;0.53 & +28.88 & 0.0 & +\;1.74 & = 0 \end{array} \tag{15}$$

When *Mars* made its near approach to ς^2 *Aquarii* on October 1, 1672, the position of the planet was compared with that of the star by RICHER at Cayenne, by PICARD near Beaufort, and by ROEMER at Paris. From a very careful discussion of these comparisons, LE VERRIER derived the equation which he has given in the *Comptes Rendus*, T. LXXV, p. 169, namely,

$$+29''.5r' + 225''.3r'' + 1398''r^{\mathrm{IV}} - 21''.86 = 0$$

By substituting in it the value of r^{IV} from Table I, the first equation of the group (15) results.

The second equation of the group (15) is from the *Annales* of the Paris Observatory, T. VI, p. 73; and is based upon the longitude of *Venus* deduced from HORROX's observation of the transit of that planet in December, 1639. The third and fourth equations are from the *Annales*, T. VI, p. 76; the former being derived from the longitudes of *Venus* obtained from BRADLEY's meridian observations, and the latter from the longitudes obtained from the meridian observations made between the years 1766 and 1830. The fifth and sixth equations are from the *Annales*, T. VI, p. 90; the former being derived from the latitudes of *Venus* resulting from the observations of the transits in 1761 and 1769, and the latter from the latitudes resulting from the Greenwich meridian observations made between the years 1751 and 1830.

In the *Annales* of the Paris Observatory, T. IV, p. 52, LEVERRIER has given the equation

$$+0''.53r \;+28''.88r' \;+0''.83r''' \;+1''.81 = 0 \tag{16}$$

which he has derived from the secular diminution of the obliquity of the ecliptic. By adding the term $+16''.01r^{\mathrm{IV}}$, from p. 51 of the *Annales*, and substituting the values of r''' and r^{IV} from Table I, the last equation of the group (15) results. In the *Annales*, T. V, p. 100, and T. VI, p. 91; and in the *Comptes Rendus*, T. LXXV, p. 168, LEVERRIER has given equation (16) in the form

$$+0''.53r \;+28''.88r' \;+0''.75r''' \;+1''.72 = 0 \tag{17}$$

but the difference arises solely from the circumstance that in (16) the assumed mass of *Mars* is 1 : 2 680 337, while in (17) it is 1 : 2 994 790. For further information respecting the equations (15), TISSERAND's paper in the *Comptes Rendus*, T. XCII, pp. 653–660 may be consulted.

From the group of observation-equations (15), the following normals result. (18)

$$\begin{array}{rrrrl}
+1017''.64r & +\;1657''.55r' & +\;1844''.16r'' & +\;552''.713 & = 0\\
+1657.55 & +\;6822.98 & +12872.10 & +\;235.835 & = 0\\
+1844.16 & +12872.10 & +58414.84 & -3393.103 & = 0
\end{array}$$

and their general solution is

$$\begin{array}{rlll}
1000r & = -1.764\,489\,702\,P & +0.553\,787\,566\,Q & -0.066\,325\,742\,R\\
1000r' & = +0.553\,787\,566 & -0.424\,651\,923 & +0.076\,091\,780\\
1000r'' & = -0.066\,325\,742 & +0.076\,091\,780 & -0.031\,792\,362
\end{array}$$

where

$$P = +552.713 \qquad Q = +235.835 \qquad R = -3\,393.103$$

We therefore have

$$\begin{aligned}
r &= -0.619\,603\,8 \;\; \pm 0.096\,92\\
r' &= -0.052\,249\,4 \;\; \pm 0.047\,55\\
r'' &= +0.089\,160\,8 \;\; \pm 0.013\,01
\end{aligned}$$

with which the residuals in the normal equations (18), are

$$+0''.0002 \quad +0''.0008 \quad +0''.0028$$

The residuals in the observation-equations (15), are

$$\begin{array}{rrrr}
-0''.043 & -6''.022 & +0''.107 & -0''.097\\
-3.228 & -0.250 & +0.192 &
\end{array}$$

and the probable error of any one of the observation-equations (15), is $\pm 2''.307$.

The equations in group (19) are from the *Annales* of the Paris Observatory, T. IV, p. 95, and depend entirely upon observations of the sun. The first equation of the group has been deduced from the differences of the maximum values of the equation of the center determined at two epochs fifty years apart. The second equation arises from the observed motion of the *Earth's* perigee; and the remaining equations are based upon the periodic perturbations of the *Earth*, the third and fifth arising from the action of *Venus*, while the fourth and sixth arise from the action of *Mars*.

$$\begin{array}{rrrrl}
-0''.23r & +1''.01r' & -0''.65r''' & -0''.21 & = 0\\
-0.43 & +5.97 & +1.93 & -0.44 & = 0\\
-0.04 & +8.00 & -0.13 & -0.01 & = 0\\
+0.02 & +1.07 & +4.00 & +0.48 & = 0\\
-0.02 & +8.00 & -0.17 & -0.09 & = 0\\
0.00 & +0.61 & +4.00 & +0.35 & = 0
\end{array} \tag{19}$$

In accordance with LEVERRIER's estimate of the relative accuracy of these equations (*Annales*, T. IV, pp. 95–96), the second will be given a weight of $\frac{1}{9}$. It then becomes

$$-0''.14r \;+1''.99r' \;+0''.64r''' \;-0''.15 = 0 \tag{20}$$

and, regarding r''' as known, the weighted normal equations are

$$\begin{array}{rrrrl}
+0''.0749r & -\;\;0''.9695r' & +0''.1485r''' & +0''.0811 & = 0\\
-0.9695 & +134.4972 & +4.9371 & -0.5835 & = 0
\end{array} \tag{21}$$

The general solution is

$$\begin{aligned}
r &= -14.725\,041\,P \;-0.106\,143\,Q\\
r' &= -\;\;0.106\,143 \qquad -0.008\,200
\end{aligned}$$

where

$$\begin{aligned}
P &= +0.1485r''' \;+0.0811\\
Q &= +4.9371 \qquad -0.5835
\end{aligned}$$

Hence

$$\begin{aligned}
r &= -2.710\,707r''' \;-1.132\,266\\
r' &= -0.056\,246 \qquad -0.003\,824
\end{aligned} \tag{22}$$

and the residuals in the normal equations (21), are

$$\begin{array}{rr}
-0''.000\,00r''' & +0''.000\,00\\
+0.000\,20 & -0.000\,09
\end{array}$$

The substitution in (22) of the value of r''' from Table I gives

$$\begin{aligned}
r &= -0.770\,229 \;\; \pm 0.317\\
r' &= +0.003\,688 \;\; \pm 0.007\,49
\end{aligned}$$

with which the residuals in the weighted observation-equations (19) and (20), are

$+0''.058$, $-0''.120$, $+0''.068$, $-0''.065$, $-0''.022$, $-0''.182$

and the probable error of any one of these equations is $\pm 0''.082\,76$.

Collecting our results: from the groups of equations (12), (13), (15) and (19), the values of r are

$$\begin{array}{rl}
-0.566\,867 & \pm 0.127\\
-0.265\,711 & \pm 1.511\\
-0.619\,604 & \pm 0.096\,92\\
-0.770\,229 & \pm 0.317
\end{array}$$

and the values of r' are

$$\begin{array}{rr}
-0.012\,330 & \pm 0.005\,75 \\
-0.055\,712 & \pm 0.035\,76 \\
-0.052\,249 & \pm 0.047\,55 \\
+0.003\,688 & \pm 0.007\,49
\end{array}$$

while from the groups of equations (13) and (15) the values of r'' are

$$\begin{array}{rr}
+0.148\,078 & \pm 0.038\,47 \\
+0.089\,161 & \pm 0.013\,01
\end{array}$$

Instead of attempting to deduce final values from these results, it will be better to reduce the various groups of equations to a uniform standard of weight, and then to solve them all simultaneously. The data for that purpose are as follows:

Equations	Prob. Error	√ Wt.
Group (12)	±0.036	10.000
" (13)	0.567	0.635
" (15)	2.307	0.156
" (19)	0.0828	4.35

The weight of the equations in group (12) is arbitrarily assumed to be 100, and then the weights for the other groups follow from the probable errors given in the second column. By the application of these weights, each to its own group of equations, the subjoined system of weighted observation equations is obtained.

$$\begin{array}{rrrrl}
-0''.659r & -11''.021r' & -\ 9''.235r'' & -0''.261 & = 0 \\
+1.119 & -50.386 & -67.175 & +1.489 & = 0 \\
+0.089 & +\ 2.959 & +10.389 & -1.300 & = 0 \\
+0.051 & +\ 0.438 & +\ 1.308 & -0.681 & = 0 \\
-0.061 & +\ 7.760 & +\ 0.019 & +0.339 & = 0 \\
-0.438 & -16.256 & -\ 4\,331 & -0.422 & = 0 \\
0.000 & +\ 1.602 & +35.147 & -2.900 & = 0 \\
-4.273 & -\ 7.227 & -\ 8.018 & -2.811 & = 0 \\
+2.231 & +\ 3.978 & +\ 4.321 & +0.265 & = 0 \\
+1.217 & +\ 1.435 & +\ 2.387 & +0.577 & = 0 \qquad (23) \\
-0.083 & +\ 3.838 & +\ 5.117 & -0.290 & = 0 \\
-0.193 & +\ 6.302 & +\ 8.424 & -0.512 & = 0 \\
+0.083 & +\ 4.505 & 0.000 & +0.271 & = 0 \\
-1.000 & +\ 4.394 & 0.000 & -0.535 & = 0 \\
-0.609 & +\ 8.656 & 0.000 & -1.022 & = 0 \\
-0.174 & +34.800 & 0.000 & +0.030 & = 0 \\
+0.087 & +\ 4.654 & 0.000 & -0.235 & = 0 \\
-0.087 & +34.800 & 0.000 & -0.291 & = 0 \\
0.000 & +\ 2.654 & 0.000 & -0.800 & = 0
\end{array}$$

The resulting normal equations are (24)

$$\begin{array}{rrrrl}
+28''.0773r & -\ \ 0''.4420r' & -\ \ 21''.3120r'' & +\ \ 19''.8172 & = 0 \\
-\ 0.4420 & +7265.9429 & +4178.6252 & -227.7718 & = 0 \\
-21.3120 & +4178.6252 & +6147.7642 & -394.2509 & = 0
\end{array}$$

and their general solution is

$$\begin{array}{lrrr}
100r = & -3.576\,684\,283\,P & +0.011\,349\,517\,Q & -0.020\,113\,276\,R \\
100r' = & +0.011\,349\,517 & -0.022\,631\,115 & +0.015\,421\,676 \\
100r'' = & -0.020\,113\,276 & +0.015\,421\,676 & -0.026\,817\,889
\end{array}$$

where

$$P = +19.8172 \qquad Q = -227.7718 \qquad R = -394.2509$$

We therefore have

$$\begin{aligned}
r &= -\ 0.655\,352\,905 \ \pm\ 0.065\,80 \\
r' &= -\ 0.007\,003\,642 \ \pm\ 0.005\,235 \\
r'' &= +\ 0.066\,617\,652 \ \pm\ 0.095\,698
\end{aligned}$$

with which the residuals in the normal equations (24) are

$$+0''.000\,001 \qquad +0''.000\,002 \qquad +0''.000\,002$$

The residuals in the weighted observation equations (23), are

$$\begin{array}{rrr}
-0''.1600 & -0''.5908 & +0''.1850 \\
-\ .3664 & -\ .4964 & +\ .0895 \\
-\ .6868 & -\ .9370 & -\ .6835 \\
-\ .6303 & -\ .0715 & -\ .0998 \\
+\ .3278 & +\ .0785 & -\ .3246 \\
-0.3097 & +0.1316 & -\ .4778 \\
 & & -0.8186
\end{array}$$

and the probable error of any one of the weighted observation-equations (23), is ±0″.3479.

As a final check on the solution, we have the relation

$$[nn] + [an]r + [bn]r' + [cn]r'' - [vv] = 0$$

which is satisfied thus:

$[nn]$	+41″.913 63
$[an]r$	−12.987 26
$[bn]r'$	+ 1.595 23
$[cn]r''$	−26.264 07
Sum	+ 4.257 53
$[vv]$	+ 4.257 31
Check	+ 0.000 22

It may be remarked that the weight factors were so chosen as to give a probable error of ±0″.360 for each of the observation-equations in the group (23), and the fact that this probable error comes out ±0″.348 seems to indicate that the relative weights were sufficiently exact. The 9th and 19th observation-equations give the largest residuals, and perhaps it might have been better to omit them, but it is not likely that their retention can have sensibly affected the corrections to the masses.

From the solution of the group of equations (23), we now have as the definitive result of this investigation

$$\text{Mass of } \textit{Mercury} = \frac{0.344\,647 \pm 0.065\,80}{3\,000\,000} = \frac{1}{8\,704\,559 \pm 1\,724\,742}$$

$$\text{Mass of } \textit{Venus} = \frac{0.992\,996 \pm 0.005\,235}{401\,847} = \frac{1}{404\,681 \pm 2\,134}$$

$$\text{Mass of } \textit{Earth} = \frac{1.066\,618 \pm 0.005\,698}{354\,936} = \frac{1}{332\,768 \pm 1\,778}$$

Or, expressed decimally.

$$\text{Mass of } \textit{Mercury} = 0.000\,000\,114\,882 \pm 0.000\,000\,021\,933$$
$$\text{Mass of } \textit{Venus} = 0.000\,002\,471\,082 \pm 0.000\,000\,013\,027$$
$$\text{Mass of } \textit{Earth} = 0.000\,003\,005\,097 \pm 0.000\,000\,016\,056$$

The substitution of this mass of the *Earth* in the expression

$$\text{Solar parallax} = [2.784\,934]\ \sqrt[3]{(\text{mass of } \textit{Earth})} \qquad (25)$$

gives

$$\text{Solar parallax} = 8''.795 \pm 0''.016$$

Respecting equation (25), it is only necessary to remark that the coefficient in brackets is the logarithm of the number which it represents, and that number is based upon the best modern values of the length of the seconds-pendulum, the length of the sidereal year, and the size and figure of the earth.

Washington, D.C., 1889 *April* 18.

THE VARIABLE STAR μ *CEPHEI*.

By Rev. JOHN G. HAGEN, S.J. (*Georgetown College*).

On the 9th of April, 1888, Mr. J. E. Gore presented to the Royal Irish Academy a series of observations of this "garnet star," extending from 1884 to 1887. These observations were published in the "Proceedings" of the Academy, 3d ser., Vol. I, No. 1.

This star was simultaneously observed by my assistant, Mr. Arthur Zaiser, and a comparison of both series will be the more interesting, as Argelander was unable to deduce the elements of variability from his sixteen years' observations, or to reconcile his results with those of the discoverer Hind and of Heis. It may be well to mention, that the period of 419 days with residual errors as large as —102 and +119 days, and the other of 132 days with the residual errors +83 and —65 days, were considered by Argelander himself as mere attempts of computation.*

Since Mr. Gore based his computations on the "Harvard Photometry" scale, I have reduced Mr. Zaiser's observations to the same scale. The table below gives the differences, in tenths of a magnitude, of the observed magnitude on each evening from the mean of all the observations; the reductions were made with two decimal places.

The larger deviations from the mean magnitude in Mr. Gore's series may be explained from the wider range of his comparison stars

$$\zeta = 3.5\,, \quad \varepsilon = 4.2\,, \quad \nu = 4.5\,, \quad 9 = 4.8\,, \quad \lambda = 5.3,$$

while Mr. Zaiser used only ζ, ε and $\iota = 3.6$, and perhaps also from the fact that Mr. Gore's observations were made, as a rule, with a binocular of two inches aperture, and Mr. Zaiser's observations with the naked eye. The letter *b* will indicate when the latter observer used an opera glass of one and one-half inches aperture.

The time of observation, with but few exceptions, was for both observers between 8 and 10 o'clock in the evening, Mr. Zaiser using "central time" (*i.e.* Greenwich time less six hours.)

The differences in the following table, when plotted on squared paper, show with great probability a *minimum phase* of the variable star in the year 1886. Mr. Zaiser's light-curve puts it in the month of August, and Mr. Gore's in September, with the magnitudes of 4.1 and 4.4, respectively. The maximum phase is not so well pronounced in either curve, that of Mr. Zaiser indicating a doubtful one in October 1885, and that of Mr. Gore in June of the same year, with the magnitude 3.7 in both cases.

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* *Beobachtungen und Rechnungen über Veränderliche Sterne*, pp. 56–57, where expressions like these, "*viel zu grosse Fehler*," "*nicht verträglich*," "*stimmen gar nicht*," etc., sufficiently characterize Argelander's own opinion on his computed results.

$$\text{Abbreviations}\begin{cases} \text{Z} = \text{Zaiser, mean magnitude} = 3^{\text{M}}.88 \\ \text{G} = \text{Gore,} \quad \text{"} \quad \text{"} \quad = 4\ .00 \\ \text{h} = \text{haze, m} = \text{moonlight, b} = \text{binocular.} \end{cases}$$

Differences in tenth of a magnitude.

	Z.	G.
1884 Sept. 12	0	
13		0
18		0
19	—1	
25	0	
Oct. 1		+1 m
10	+2	
16	+1	0
Nov. 2		—2 m
7	0	
9		—4
12		—1
18	0	
21		—2
Dec. 9	0	
17	+3 h	
21		—1
1885 Jan. 5		—2
9	0	
13		—1
30		—3 m
Feb. 3		—3
11	+1	
13		—4 h
14		—3
18		—3
22		—3 m
24		—3
26		—2
Mar. 6		0
7	+1 b	
9	0 b	
11		—2
13		—1
22		—3
27		—3 m
Apr. 3	0 b	
10	+1 b	
May 3	+1 b	
9	—1 b	
11		—4
13	+1 bh	
June 4	—1 b	
15	0 bh	
17	—1 m	
July 2	—2	
6	—3 h	
28		—4 m
1885 July 30		—4 m
Aug. 13		—4
14	—1	
19		—3 m
Sept. 7		—2
9		+2
13		0
14	—1 m	
16		0 m
30		0
Oct. 1	—1	
5	—2	
9	—1	
12		0
22		—1 m
Nov. 1		+1
9	—1	
15		0 m
21		—1 m
30		—2
Dec. 1		—1
6	—2	
9		—2
11	—1	
16		—2 m
22		—2
1886 Jan. 6	+1 bh	
9	+1	
13		—2 m
16		—2 m
Feb. 1	—1	
3		—1
8	+2 bh	
14		—1
22	—1	
Mar. 2	0	
3		—2
6	—1	—1
10		—1 mb
13		—1 m
17		—1 m
21	—2 b	
29		0
Apr. 2	0 b	—1 h
6	—1 b	
7		+1
14		+1 m
16		+1 m
1886 Apr. 27	+3 b	+2
28		+2
May 1	+1 b	
6	+3 bh	
14		+1 m
18	0 bm	
19		0
21		+1
22		+1
26		+1
27	+3 b	
29	—1 bh	
June 2	+1	
12		+1
17	+3 b	
29	+3	
July 1	+1 h	
5	+3	
21		+1
Aug. 14		+4 m
22	+4	+5
28		+5
29		+4
31		+4
Sept. 2		+4 m
3		+4 m
6		+3 m
8		+4 m
14		+3 m
15		+3
16		+4
17		+4
18		+4
20		+4 h
22		+4
27		+4
Oct. 1	0	+4
10		+4 m
12		+3 m
16		+4
18	+2	
20		+3 h
23		+3
24		+3
25		+3
26		+1 h
28		+3 h
29	—1	
31		+4
1886 Nov. 1		+4
3		+3 m
4		+3 m
8		+3 m
10		+3 m
16		+3
20		+3
23		+1
25	+2	
26		+3
28		+3
30		+1
Dec. 12		+1 m
13		+1 m
15	0	
16		+1
22		+1
24		+1
25		+1
27		+1 h
29	+3	
30		+1
1887 Jan. 14	+2	
28	—1	
Feb. 5		—1 m
8		+1 m
10		+1 m
11		+1
12	—1	
16	—1	
Mar. 13	+1 b	
15		+1
17	—2	
24	—2 b	
28	—2 b	
29		0
Apr. 6		—1 m
8		—1 m
12		—1
16		—1
18	—2 b	
20	0 b	
25	—2 b	
May 15	0 b	
19	—2	
June 14	—2	

CORRIGENDUM.

No. 191, p. 183, col. 1, line 6, *for* Third *read* Fourth.

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On the Masses of Mercury, Venus and the Earth, and on the Solar Parallax, by Prof. William Harkness.
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Corrigendum.

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SYSTEMATIC CORRECTIONS OF STAR-POSITIONS NEAR THE EQUATOR, WITH A NOTE ON THE CONSTANTS OF SOLAR MOTION.

BY LEWIS BOSS.

The preparation of the catalogue, founded upon observations made at Albany for the zone $+0° 50'$ to $+5° 10'$ of declination, under the well known programme of the *Astronomische Gesellschaft*, presented the occasion and motive for a study of the systematic peculiarities of certain older catalogues and series of observations, within the limits of the Albany zone. The question presented a practical bearing in its relations to the computation of systematically accurate proper-motions for telescopic stars. If, for example, one takes a series of stars whose positions are determined both in the zones of Lalande and Bessel, and compares the uncorrected positions, obtained by these observers, with the corresponding determinations contained in the Albany zone, it will be found that the annual proper-motion resulting from the comparisons with Lalande in certain hours of right-ascension will systematically differ by fully $0^s.005$ in the R.A. and $0''.05$ in the declination coordinate, from the corresponding proper-motion derived from Bessel. These are quantities so great that the neglect of them is calculated to produce a feeling of hopeless uncertainty when one is dealing with the smaller proper-motions of the telescopic stars, the majority of which, for the earlier dates, must depend chiefly upon the zones of Bessel and Lalande.

For the first step in the process of ascertaining the systematic correction required by certain star-catalogues, within the limits of the Albany zone, a Special Catalogue of standard stars was constructed, with which each of the authorities for star-positions was compared. As a convenient basis for the construction of the Special Catalogue, the "*Fundamental-Catalog für die Zonen-Beobachtungen*" by Auwers was adopted, for reasons which will appear. It is the standard catalogue upon which the Albany positions depend, and with which the latter probably agree sufficiently well in the systematic sense. It is clear that for the first approximation to the systematic corrections it is not necessary or even very important that the standard catalogue of comparison shall be free from systematic error. It is only important that the positions be relatively good in the sense of casual error. It is clear, therefore, that the *Fundamental-Catalog* may be enlarged for the present purpose by the addition of all the stars observed by Bradley, and catalogued by Auwers, which are at the same time contained in the Albany zone; and that the positions and proper-motions so computed will be in general systematic accordance with those of the *Fundamental-Catalog*, and particularly with those of the 23 stars of that catalogue which are contained within the limits of the Albany zone. Relatively to the determinations of D'Agelet, Piazzi, Bessel, Rümker, Argelander (Bonn VI), and Schjellerup, the intermediate positions calculated from this Special Catalogue, for comparison with the catalogues enumerated at the respective dates, will possess a high degree of accuracy (except in cases where Argelander has employed all the transit-threads and four microscopes), and will therefore be practically as effective for the purposes of this discussion as might have been a much more elaborately constructed standard catalogue. In this way I was enabled to enlarge the list of 23 fundamental stars to a Special Catalogue of 151 stars (148 in α and 143 in δ).

Obviously the systematic discordance, c_1 and c'_1, of the positions of any catalogue, subtracted from those of this Special Catalogue, must be corrected by the amount of systematic correction, c_2 and c'_2, required to bring the positions of the Special Catalogue into systematic accordance with the Normal System to be eventually adopted, before the true correction, c_0 and c'_0, required by any individual catalogue can be ascertained. We have: $c_1 + c_2 = c_0$; $c'_1 + c'_2 = c'_0$. An enumeration of the catalogues and series of observations treated in this discussion follows, with such brief remarks regarding each as seem necessary to elucidate the subsequent investigation.

D'Agelet. The reduction of D'Agelet's observations by Gould (*Mem. N.A.S.* Vol. I) is employed. The discussion for systematic correction for this catalogue must be founded on a wider range of declination and with more numerous points of comparison in the standard catalogue than were available in the present investigation. The stars of this catalogue are rarely below the eighth magnitude, and therefore an exact knowledge of the systematic correction required by it is not so important for the immediate purpose here contemplated.

effect of this upon the relative values of $\Delta\alpha$ and $\Delta\delta$ in the successive means (order of R.A.) is not important. For LALANDE and BESSEL, and to a less extent for SCHJELLERUP, the constant errors of the individual zones are more effective in determining the values of $\Delta\alpha$ and $\Delta\delta$ for the successive groups than is the mere casual error. Whenever it becomes possible to ascertain, with sufficient accuracy, the constant error of each zone, through comparison with a standard catalogue containing a sufficient number of well determined positions with corresponding proper-motions, the purposes of an investigation like the present will be immensely facilitated. Zones 1, 2, 5 and 7 of BESSEL, all of which would otherwise have been included in the group of 20^h, are excluded from this discussion because of the very large constant errors in right-ascension which they contain.

DIRECT COMPARISON WITH ALBANY CATALOGUE FOR STARS WITH (NEGLECTED) SMALL, OR NO, PROPER-MOTION. TABLE III.

	ALBANY—LALANDE'S ZONES						ALBANY—BESSEL'S ZONES						ALB.—ARGEL.		
	$1^{\rm M}$ to $7^{\rm M}$			$7^{\rm M}.8$ to $10^{\rm M}$			$7^{\rm M}$ to $8^{\rm M}$			$8^{\rm M}.9$ to $10^{\rm M}$					
	Obs.	$\Delta\alpha$	$\Delta\delta$	Obs.	$\Delta\alpha$	$\Delta\delta$	Obs.	$\Delta\alpha$	$\Delta\delta$	Obs.	$\Delta\alpha$	$\Delta\delta$	Stars	$\Delta\alpha$	$\Delta\delta$
h		s	"		s	"		s	"		s	"		s	"
0							93	—0.19	—0.8	302	—0.19	—1.2	83	—0.06	—1.6
2	50	+0.08	—3.6	245	+0.08	—3.8	76	—0.20	—2.2	187	—0.29	—2.1	43	—0.08	—1.9
4							127	—0.12	—1.2	388	—0.13	—1.0	47	—0.06	—0.5
6	69	+0.11	—3.7	355	+0.10	—3.3	98	—0.16	—0.7	395	—0.12	—0.6	115	—0.04	—1.1
8							113	—0.06	—0.1	352	—0.12	—0.4	140	—0.05	—0.7
10	87	—0.11	—2.7	234	—0.03	—2.2	101	—0.14	—0.1	258	—0.15	—0.2	26	—0.09	—1.6
12							72	—0.22	0.0	191	—0.14	+0.4	37	—0.09	—0.8
14	75	—0.06	—2.5	237	0.00	—2.8	101	—0.26	+1.2	288	—0.22	+1.4	44	—0.10	—0.8
16							113	—0.15	0.0	321	—0.13	+0.4	39	—0.11	—1.6
18	127	+0.07	—3.5	318	+0.07	—3 1	170	—0.12	+0.1	331	—0.09	—0.3	96	—0.10	—1.2
20							59	—0.26	+0.1	220	—0.22	—0.5	95	—0.09	—1.5
22	55	+0.14	—3.3	298	+0.14	—4.0	31	—0.32	—1.2	200	—0.31	—1.6	54	—0.04	—1.2
General means	463	+0.04	—3.2	1687	+0.06	—3.2	1145	—0.16	—0.34	3436	—0.16	—0.45	819	—0.070	—1.16
Uncorrected means		+0.07			+0.12			—0.12			—0.09			—0.000	

	ALBANY—SCHJELLERUP.											
	$6^{\rm M}.3$ to $8^{\rm M}.1$			$8^{\rm M}.2$ to $8^{\rm M}.6$			$8^{\rm M}.7$ to $9^{\rm M}.5$			Mean of all		
	Stars	$\Delta\alpha$	$\Delta\delta$	Stars	$\Delta\alpha$	$\Delta\delta$	Stars	$\Delta\alpha$	$\Delta\delta$	Stars	$\Delta\alpha$	$\Delta\delta$
h		s	"		s	"		s	"		s	"
0	45	+0.04	—1.1	29	+0.05	—0.5	75	+0.06	—1.0	149	+0.053	—0.96
2	22	—0.01	—0.9	21	—0.08	—0.9	34	—0.03	—0.6	77	—0.037	—0.74
4	28	+0.07	—0.5	19	+0.02	—1.6	39	—0.02	—0.4	86	+0.015	—0.69
6	34	+0.06	—0.8	21	+0.09	—0.7	33	+0.05	—0.9	88	+0.063	—0.80
8	13	+0.02	—1.7	17	+0.05	—1.9	34	+0.10	—1.5	64	+0.070	—1.67
10	22	+0.01	—1.1	19	+0.02	—1.0	51	+0.02	—0.8	92	+0.019	—0.91
12	27	—0.04	—0.6	16	—0.04	—0.6	42	0.00	—0.4	85	—0.019	—0.54
14	8	—0.01	—0.9	19	+0.01	—0.1	22	—0.02	—0.3	49	—0.005	—0.34
16	22	—0.01	—0.6	28	+0.01	—0.7	48	—0.03	—0.4	98	—0.013	—0.50
18	39	+0.02	—0.6	39	+0.04	—0.6	59	+0.02	—0.6	137	+0.026	—0.58
20	34	+0.07	—1.0	32	+0.07	—0.7	68	+0.07	—1.0	134	+0.075	—0.92
22	23	+0.11	—1.3	20	+0.10	—1.1	51	+0.07	—0.8	94	+0.086	—1.01
General means	317	+0.033	—0.89	280	+0.034	—0.82	556	+0.031	—0.75	1153	+0.032	—0.81
Uncorrected means		+0.073			+0.094			+0.101			+0.094	

Comparing the general mean values of $\Delta\alpha$ for each catalogue, and for the groups in order of magnitude, it appears that they are more accordant when the Albany right-ascensions are corrected for personal equation dependent on magnitude. This accordance is practically perfect for BESSEL and SCHJELLERUP; while the discordance is marked for the uncorrected means. This might be accepted as conclusive evidence, 1°, that the adopted correction of Albany right-ascensions for personal equation dependent on magnitude is valid; 2°, that no such term of correction of sensible amount is required by the observations of LALANDE, BESSEL or SCHJELLERUP. But when we compare the corrected general means of $\Delta\alpha$, from Table III, with the general means for the respective authorities in Table I, the discordance is marked. In fact, it is to be noted that the uncorrected mean values of $\Delta\alpha$ in Table III, in the combined general mean for each catalogue, accord almost perfectly with those from Table I. This might be held to point to the conclusion either that the

Albany right-ascensions should not be corrected for personal equation dependent on magnitude, or that this correction is practically identical for all the four catalogues concerned. The latter assumption must in any case be regarded as highly improbable. But other explanations may be found for this state of facts. The results of Tables I and III may differ on account of the erroneous values of Struve's precession-coefficients, since the general means for $\Delta\alpha$ in Table I would be practically free from the effect of such an error; while those for Lalande, Bessel and Schjellerup, in Table III, would contain the effect of the error in Struve's m multiplied by 84, 58 and 18 respectively. In the second place, the values of $\Delta\alpha$ in Table I are influenced by whatever the systematic correction of the Special Catalogue may be for the respective epochs of the various catalogues compared; while those of Table III are affected by the systematic error of the Albany catalogue (for the mean epoch 1880.5) alone. It will hereafter appear that the greater part of the discordances, between the corrected values of $\Delta\alpha$ in Table III and those of Table I, may be cleared up on the assumption that they are due to the systematic errors of the Special Catalogue.

The following table contains some of the more important cases of discordance in the mean values of $\Delta\alpha$ and $\Delta\delta$ found in the progress of the examination of Lalande's and Bessel's zones.

Table IV.*

Albany—Lalande's Zones

H.C. p.	$\Delta\alpha$	$\Delta\delta$
	s	$''$
46†	–	-5.6
91	–	$-3.8 - 1''.0\,(T-18^h.0)$
94	–	$-3.1 + 1\ .3\,(T-18\ .0)$
107	–	-4.5
109	$+0.40$	-4.2
184	–	-4.8
201	$+0.30$	-6.4
230	-0.13	–
231	-0.06	–
256	$+0.09 - 0^s.09\,(T-7^h.0)$	–
336	$+0.34$	–
464	$+0.54$	-4.7

Albany—Bessel's Zones

Zone	$\Delta\alpha$	$\Delta\delta$
	s	$''$
1	-0.50	–
2	-0.57	–
5	-0.43	-3.9
6	-0.50	-4.8
7	-0.33	-4.3
8	-0.39	-2.5
45	$-0.23 - 0^s.13\,(T-7^h.0)$	–
47	$+0.22$	–
59	-0.44	–
75	–	$+4.7$
130	$-0.36 - 0^s.19\,(T-1^h.8)$	–

Other zones might be added to this list, which present discordances nearly as great. It is evident that no great precision can be expected in the derivation of systematic corrections for these observations if such discordances are neglected. But the persistence of sign is fairly well marked throughout all the zones not included in the foregoing enumeration, and zones including 10 observations or less (in the limits of the Albany zone), like zones 6, 8 and 75 of Bessel, were excluded from the means of Table III.

Before computing concluded values of c_1 and c'_1 from the Tables I and II, it is necessary to notice that the right-ascensions of the Special Catalogue, other than those of the 23 fundamental stars, do not strictly conform to the system of the *Fundamental-Catalog* if we suppose that the correction for personal equation dependent on magnitude is valid. The average magnitude of these additional stars is almost exactly $6^M.0$, for which the personal-equation correction is $0^s.022$, corresponding to the epoch 1880.5. We shall therefore have for the correction of the Special Catalogue at any epoch, T, $-0^s.022 \times \frac{125}{148} \times \frac{1}{125}\,(T-1755.0)$. Considering the second decimal only, this correction will be $0^s.00$ for D'Agelet, $-0^s.02$ for Schjellerup, and $-0^s.01$ for each of the six other authorities. Adding these corrections to the general means for $\Delta\alpha$ in Table I, and computing periodic terms where they appear to be sensible, we have:

Mean Values of c_1 and c'_1. Table V.

D'Agelet	$c_1 = +0^s.11$	$c'_1 = -1''.8$
Piazzi	$+0.16$	$-2.92 + 0''.39 \sin(\alpha + 339^\circ)$
Lalande's zones	$+0.11$	$-2.47 + 0.38 \sin(\alpha + 319)$
Bessel's zones	$-0.135 + 0^s.101 \sin(\alpha + 291^\circ)$	$-0.10 + 1.32 \sin(\alpha + 227)$
Struve, 1830	$+0.02$	-1.2
Rümker	$+0.07$	$-0.14 + 0.70 \sin(\alpha + 282)$
Schjellerup	$+0.07$	-0.6

---

[*] To reduce to the normal system finally adopted, the corrections to the above values of $\Delta\alpha$ and $\Delta\delta$ are, for Lalande's zones, $-0^s.05$ and $+0''.2$ respectively; and for Bessel's zones, $-0^s.06$ and $+0''.2$. To these might properly be joined the effect of secular parallactic motion for ninth-magnitude stars, as hereafter determined, which may be taken for Lalande: $+0^s.090 \sin(\alpha-267^\circ)$ and $-1''.5$; and for Bessel: $+0^s.062 \sin(\alpha-267^\circ)$ and $-1''.05$. Thus the entire correction of the above values to find the real corrections to the normal system, are for Lalande: for $\Delta\alpha$, $-0^s.05 - 0^s.090 \sin(\alpha-267^\circ)$; for $\Delta\delta$, $+1''.7$; and for Bessel's zones: for $\Delta\alpha$, $-0^s.06 - 0^s.062 \sin(\alpha-267^\circ)$; for $\Delta\delta$, $+1''.25$, which quantities must be numerically added to those taken from Table IV in order to obtain the true systematic corrections for these zones.

† Applies to observations after 5^h of R. A.

The evidence in favor of the periodic terms for Piazzi, Lalande's zones and for Rümker, is very slight, so far as the comparison with the *Special Catalogue* is concerned; but since Von Asten's tables, which are based on Piazzi's catalogue, were employed in computing Lalande's positions for 1800, the correction required by Lalande's zones so reduced should closely resemble that required by Piazzi's catalogue. The two formulas, therefore, by their close agreement from independent calculation greatly increase the probability in favor of each. In fact, I have elsewhere found (*Declinations of Fixed Stars*, App. *II*, Report U.S. Northern Boundary Commission, Washington, 1878) that Piazzi's declinations, from +40° to —30° of declination, appear to require a correction of the form:

$$+0''.56 \sin(\alpha+341°).$$

The normal system of star-positions selected as a basis to which the final corrections, c_0 and c'_0, will be referred, is that of the *American Ephemeris* for 1881 and subsequent years. This depends for right-ascension on Newcomb's well known paper upon the Right-Ascensions of the Fundamental Stars, (App. III, *Washington Astr. and Meteor. Observ.* for 1870), and for declination upon my own work entitled, *Declinations of Fixed Stars* (App. *II*, Report U.S. Northern Boundary Commission, Washington, 1878). A statement of the reasons which governed this choice would extend this article beyond desirable limits, and is omitted.

(*Concluded in next number.*)

OBSERVED MAXIMA AND MINIMA OF VARIABLE STARS IN 1888 AND 1889,

By P. S. Yendell.

S Ursae Majoris.

A series of observations of this variable, 24 in number, extending from 1888 Nov. 28 to 1889 Mar. 22, indicates a maximum, at $6^{\mathrm{M}}.7$, 1889 Feb. 18. This and the preceding maximum are interesting on account of their departure from the usual light-curve of the star, which is characterized by Mr. Chandler on page 165 of Vol. VIII of this Journal as "unusually flat" at the maximum. In each of the last two maxima, during the nine or ten weeks preceding this phase, there were two sharp fluctuations in the rising curve, which, upon plotting the two curves together, coincide closely in time and amplitude, and a final rapid upward rush to the maximum, also shown at both times; after the maximum the light fell away with equal suddenness, fixing the time of this phase quite closely.

T Ursae Majoris.

This star presented nothing unusual at its maximum, which occurred 1889 Jan. 13. It was first observed 1888 Nov. 9, rising quite rapidly to a magnitude of $7^{\mathrm{M}}.7$ about 1889 Jan. 1; at this brightness it remained until Jan. 25, after which it declined, rather less rapidly than it increased. At the last observation, 1889 Mar. 22, its magnitude was about $9^{\mathrm{M}}.2$, and its decline had become quite gradual.

R Lyrae.

Of *R Lyrae*, two maxima and two minima have been observed, as follows.

Maxima	Minima
1888 December 3	1888 December 21
1889 January 14	1889 February 9

Dorchester, Mass., 1889 *May* 6.

R Corvi.

Unfavorable weather has to a great extent interfered with observation of this star, and only six observations have been obtained between 1889 Mar. 30 and April 30. These indicate that a maximum was passed on or about 1889 April 9, and give a suggestion of a secondary maximum about May 1.

Algol.

A single minimum of *Algol* was obtained from 11 naked-eye observations, 1888 Dec. 6^{d} 9^{h} 15^{m} Cambridge mean time.

Y Cygni.

Minima were observed as follows, with telescope of $4\frac{1}{4}$ inches.

1888 Sept. 10^{d} 12^{h} 51^{m} from 12 observations.
" 28 12 54 " 13 "
Oct. 10 13 23 " 17 "

The full aperture was used on the first date; but only three inches of it on the others.

U Cephei.

Minima were observed as follows, with telescope of $4\frac{1}{4}$ inches.

1888 Oct. 10^{d} 11^{h} $18^{\mathrm{m}}.4$ from 19 observations.
1889 April 30 9 45 " 3 "
May 5 9 16.5 " 11 "

The observations on April 30 were made with the purpose only of obtaining the star's light at minimum; but on reducing them they were found to indicate a minimum, and it is here given for what it is worth.

The star's observed light at minimum on 1888 Oct. 10 was = Glasenapp's comparison star d: on 1889 April 30 it was 2 steps $> d$, as also May 5.

TWO HUNDRED EIGHTY-FOURTH ASTEROID.

A planet of the twelfth magnitude was discovered May 29, at Nice, in the position,

1889 May 29.4014 Gr. M.T. $\alpha = 14^{\mathrm{h}}\ 21^{\mathrm{m}}\ 11^{\mathrm{s}}.8$ $\delta = 14°\ 22'\ 32''$ Daily motion, -32^{s} in α, and $8'$ northward.

THE WHITE SPOT ON THE RING OF *SATURN*,

By Prof. A. HALL.

[Communicated by the Superintendent of the Naval Observatory.]

My experience in observing this spot having been different from that of most observers, it may be worth while to give it. The first note in my hand-book is as follows:

"1889 *March* 13, 9^h. *Received* Ritchie's *telegram announcing* Terby's *discovery of white spot on Ring of Saturn near shadow of Ball. This looks to me like the effect of contrast between shadow and surface of Ring, and such as has been noticed before.*"

The spot was next observed on March 17, during several hours, but it showed no motion. Mr. G. Anderson, assistant, could not see it. I have, however, continued to see this spot from March 13 until May 15. With high powers it becomes less distinct. On several occasions I have called the attention of visitors, some of them experienced observers, to the spot, and have found that very few of them could see it even when told where to look. On May 3 I was at the Washburn Observatory, and found that the astronomers there, Professors Comstock and Brown, and Mr. Egbert, had not seen this spot. I saw it with the 15½-inch refractor of that Observatory very much as it appears in the 26-inch refractor at Washington.

Since many observers have not been able to see this spot, and as it shows no motion, I conclude that it is not real, and is probably the effect of contrast.

1889 *May* 16.

SUN-SPOT OBSERVATIONS,

By H. V. GUMMERE.

On the 6th of May, while observing the sun, a group of three spots was discovered very close to the following limb, having evidently just appeared by rotation. Nothing unusual was noticed about the group. On the following day, however, more spots were visible, and a well defined penumbra had appeared *on the side of the spot furthest from the limb*. Drawings of the spot were immediately made both by Prof. Leavenworth and myself, which agreed very well in general outline, and a combined copy of which is inclosed. The penumbra seemed darkest just above the two principal spots, but just between them appeared a sharply defined white line. The following day, drawings were again made. The penumbra had almost entirely disappeared from around the smaller spot, while the larger one appeared broken into three with the penumbra contracted into a semicircle on its left. The next day the penumbra was entirely gone. During the whole time no trace of a penumbra was seen on the side nearest the limb. The observations were made with an 8¼-inch refractor provided with a Merz helioscope.

Haverford College, 1889 *May* 10.

EPHEMERIS OF COMET *e* 1888,

By C. W. CROCKETT.

[Continued from No. 192.]

1889 Gr.M.T.	App. α	App. δ	log r	log Δ	Br.
	h m s	° ′ ″			
June 30.5	21 45 18.0	+1 25 46	0.41361	0.26262	2.4
July 1.5	42 4.2	1 19 24			
2.5	38 47.5	1 12 45	0.41638	0.25898	2.4
3.5	35 28.1	1 5 50			
4.5	32 6.0	0 58 38	0.41914	0.25582	2.4
5.5	28 41.3	0 51 10			
6.5	25 14.3	0 43 26	0.42190	0.25318	2.4
7.5	21 45.1	0 35 27			
8.5	18 13.9	0 27 14	0.42465	0.25111	2.4
9.5	14 40.8	0 18 46			
10.5	11 6.0	0 10 3	0.42739	0.24963	2.4
11.5	7 29.8	+0 1 7			
12.5	3 52.3	—0 8 1	0.43013	0.24878	2.4
13.5	21 0 13.8	0 17 22			
14.5	20 56 34.4	0 26 54	0.43285	0.24858	2.4
15.5	52 54.5	0 36 37			
16.5	49 14.2	0 46 30	0.43557	0.24904	2.3
17.5	20 45 33.7	—0 56 32			
July 18.5	20 41 53.3	—1 6 42	0.43828	0.25017	2.3
19.5	38 13.2	1 17 00			
20.5	34 33.6	1 27 25	0.44098	0.25197	2.2
21.5	30 54.8	1 37 56			
22.5	27 16.9	1 48 32	0.44367	0.25445	2.2
23.5	23 40.2	1 59 12			
24.5	20 5.0	2 9 55	0.44636	0.25758	2.1
25.5	16 31.4	2 20 41			
26.5	12 59.7	2 31 28	0.44904	0.26135	2.1
27.5	9 30.0	2 42 16			
28.5	6 2.1	2 53 3	0.45170	0.26574	2.0
29.5	20 2 37.3	3 3 50			
30.5	19 59 14.7	3 14 35	0.45435	0.27070	1.9
31.5	55 54.8	3 25 18			
Aug. 1.5	52 37.8	3 35 58	0.45699	0.27621	1.9
2.5	49 23.9	3 46 31			
3.5	46 13.1	3 57 6	0.45963	0.28222	1.8
4.5	19 43 5.1	—4 7 33			

1889 Gr.M.T.	App. α	App. δ	log r	log Δ	Br.
	h m s	° ′ ″			
Aug. 5.5	19 40 1.1	—4 17 55	0.46225	0.28870	1.7
6.5	37 0.3	4 28 11			
7.5	34 2.9	4 38 20	0.46486	0.29560	1.6
8.5	31 9.0	4 48 22			
9.5	28 18.7	4 58 18	0.46716	0.30288	1.6
10.5	25 32.1	5 8 7			
11.5	22 49.2	5 17 48	0.47006	0.31049	1.5
12.5	20 10.0	5 27 21			
13.5	17 34.6	5 36 46	0.47264	0.31838	1.4
14.5	15 3.0	5 46 2			
15.5	12 35.1	5 55 10	0.47521	0.32653	1.4
16.5	10 10.9	6 4 10			
17.5	7 50.5	6 13 1	0.47776	0.33488	1.3
18.5	5 33.8	6 21 44			
19.5	3 20.8	6 30 18	0.48031	0.34341	1.2
20.5	19 1 11.5	6 38 43			
21.5	18 59 5.9	6 47 0	0.48285	0.35207	1.2
22.5	57 4.0	6 55 8			
23.5	55 5.6	7 3 7	0.48538	0.36084	1.1
24.5	53 10.8	7 10 58			
25 5	51 19.5	7 18 40	0.48789	0.36969	1.1
26.5	49 31.6	7 26 14			
27.5	47 47.2	7 33 39	0.49039	0.37859	1.0
28.5	46 6.2	7 40 56			
29.5	44 28.4	7 48 5	0.49288	0.38751	0.9
30.5	42 53.9	7 55 6			
31.5	41 22.6	8 1 58	0.49536	0.39643	0.9
Sept. 1.5	39 54.5	8 8 43			
2.5	38 29.4	8 15 20	0.49783	0.40533	0.9
3.5	37 7.3	8 21 49			
4.5	35 48.2	8 28 11	0.50029	0.41419	0.8
5.5	34 32.0	8 34 26			
6.5	33 18.7	8 40 33	0.50274	0.42299	0.8
7.5	32 8.1	8 46 33			
8.5	31 0.2	8 52 26	0.50517	0.43172	0.7
9.5	29 55.0	8 58 12			
10.5	28 52.4	9 3 51	0.50759	0.44037	0.7
11.5	27 52.3	9 9 24			
12.5	26 54.6	9 14 50	0.51000	0.44893	0.7
13.5	25 59.4	9 20 10			
14.5	25 6.6	9 25 23	0.51240	0.45740	0.6
15.5	24 16.1	9 30 31			
16.5	23 27.8	9 35 32	0.51479	0.46575	0.6
17.5	18 22 41.7	—9 40 27			
Sept. 18.5	18 21 57.8	— 9 45 16	0.51717	0.47399	0.
19.5	21 16.0	9 50 0			
20.5	20 36.3	9 54 38	0.51954	0.48210	0.
21.5	19 58.6	9 59 10			
22.5	19 22.8	10 3 37	0.52189	0.49009	0.
23.5	18 49.0	10 7 59			
24.5	18 17.0	10 12 15	0.52423	0.49795	0.
25.5	17 46.8	10 16 26			
26.5	17 18.4	10 20 33	0.52656	0.50567	0.
27.5	16 51.8	10 24 34			
28.5	16 26.8	10 28 31	0.52888	0.51326	0.
29.5	16 3 5	10 32 22			
30.5	15 41.8	10 36 9	0.53119	0.52070	0.
Oct 1.5	15 21.6	10 39 51			
2.5	15 3.0	10 43 28	0.53349	0.52800	0.
3.5	14 45.8	10 47 1			
4.5	14 30.1	10 50 30	0.53577	0.53515	0.
5.5	14 15.8	10 53 54			
6.5	14 2.8	10 57 14	0.53805	0.54216	0.
7.5	13 51.2	11 0 30			
8.5	13 40.8	11 3 41	0.54031	0.54902	0.
9.5	13 31.7	11 6 48			
10.5	13 23.9	11 9 51	0.54256	0.55574	0.
11.5	13 17.3	11 12 50			
12.5	13 11.8	11 15 44	0.54480	0.56231	0.
13.5	13 7.4	11 18 35			
14.5	13 4.2	11 21 22	0.54704	0.56873	0.
15.5	13 2.0	11 24 5			
16.5	13 0.9	11 26 45	0.54926	0.57501	0.
17.5	13 0.8	11 29 21			
18.5	13 1.8	11 31 53	0.55147	0.58115	0.
19.5	13 3.7	11 34 21			
20.5	13 6.5	11 36 46	0.55366	0.58714	0.
21.5	13 10.2	11 39 7			
22.5	13 14.9	11 41 25	0.55585	0.59298	0.
23.5	13 20.5	11 43 39			
24.5	13 26.9	11 45 49	0.55802	0.59868	6.
25.5	13 34.2	11 47 56			
26.5	13 42.2	11 49 59	0.56018	0.60424	0.
27.5	13 51.1	11 51 59			
28.5	14 0.7	11 53 56	0.56234	0.60966	0.2
29.5	14 11.1	11 55 50			
30.5	14 22.1	11 57 40	0.56448	0.61494	0.2
Oct. 31.5	14 33.8	11 59 27			
Nov. 1.5	18 14 46.2	—12 1 10	0.56662	0.62007	0.2

Troy, N.Y., 1889 *May* 31.

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SYSTEMATIC CORRECTIONS OF STAR-POSITIONS NEAR THE EQUATOR, WITH A NOTE ON THE CONSTANTS OF SOLAR MOTION.

By LEWIS BOSS.

It is now in order to ascertain the systematic corrections, c_2 and c'_2, necessary to reduce the positions and proper motions of the *Fundamental-Catalog* to the adopted normal system. In the work already cited, Newcomb gives the correction for Bessel's reduction of Bradley's observations as $-0^s.01$, neglecting small periodic terms which are evidently of no practical importance.

The new reduction by Auwers has been most exhaustively compared by him with that of Bessel; and the relation between the two is of a somewhat complicated form. It may be simplified for the present purpose by considering only that portion of Bradley's catalogue which lies within the limits of the Albany zone. In this region the mean difference, Auwers—Bessel, is $+0^s.053$; hence we have, for Newcomb—Auwers's Bradley, $-0^s.063$. (For all the stars south of the Greenwich zenith Auwers finds $+0^s.041$ for Auwers—Bessel, and therefore Newcomb—Auwers's Bradley $= -0^s.051$.) In computing the positions of his *Fundamental-Catalog* Auwers began with the Pulkowa catalogue for 1865 as a basis, having first corrected the right-ascensions to Newcomb's normal system. For stars near $+3°$ of declination we have, accordingly, as the correction of the *Fundamental-Catalog* to the adopted normal system.

$$c_2 = +0^s.0005\ (T-1865).$$

I have elsewhere* found for declination and proper-motion as the relation,

Normal—Auwers's Fundamental Catalog.

δ	$\Delta\delta$	$\Delta\mu$
°	″	″
−10	+0.30	−0.012 $(T-1875)$
0	+0.25	−0.014
+10	+0.18	−0.012
+20	+0.10	−0.011
+30	+0.04	−0.015
+40	+0.01	−0.012
+50	−0.03	−0.005
+60	−0.06	0.000
+70	−0.08	+0.003
+80	−0.10	+0.004

But in order to determine the correction more especially for the region under discussion, I have made a comparison between my standard declinations and proper-motions and those of the *Fundamental-Catalog* of Auwers, confining the discussion to stars situated between the parallels of $+15°$ and $-10°$ of declination, with the following result.

R.A.	Stars	$\Delta\delta$	$\Delta\mu'$
h		″	″
0	11	+0.25	−0.0097
4	9	+0.18	−0.0093
8	5	+0.13	−0.0198
12	5	+0.10	−0.0152
16	8	+0.24	−0.0139
20	14	+0.26	−0.0126
General means	52	+0.217	−0.0126

There is here some evidence favoring the hypothesis of periodicity in R.A. for the values of $\Delta\delta$ and $\Delta\mu$; but I have shown in the article previously cited that such a term is probably insensible when all declinations are taken into account. I therefore adopt for the correction in declination. Normal—Auwers (F.C.),

$$c'_2 = +0''.217 - 0''.0126\ (T-1875).$$

Adding these values of c_2 and c'_2 to the quantities in Table V, we have the final values of c_0 and c'_0 for the various catalogues, so far as these result from the comparisons with the Special Catalogue. It will be desirable in some cases, however, to derive them from other sources also. If we disregard the possible error of Struve's precession-coefficients, as well as the effects of parallactic motion, neglected proper-motion and other neglected secular terms which may affect the positions of stars when transferred from one epoch to another, we may obtain values of c_0 and c'_0 from Table III by applying to it the systematic correction due to the Albany catalogue for 1880.5. From the foregoing values of c_2 and c'_2 this becomes: $+0^s.008$ in R.A., and $+0''.15$ in Decl.

Newcomb has investigated the correction, c_0, to his system required by the right-ascensions of Piazzi and Struve (1830); and I have elsewhere (*Decl. Fixed Stars*) computed c' for these authorities. The corrections for D'Agelet, Lalande, Bes-

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* Proceedings of the Am. Assoc. Adv. Sci., Saratoga Meeting, 1879, pp. 119-121.

1889 Gr.M.T.	App. α	App. δ	log r	log Δ	Br.
	h m s	° ′ ″			
Aug. 5.5	19 40 1.1	−4 17 55	0.46225	0.28870	1.7
6.5	37 0.3	4 28 11			
7.5	34 2.9	4 38 20	0.46486	0.29560	1.6
8.5	31 9.0	4 48 22			
9.5	28 18.7	4 58 18	0.46716	0.30288	1.6
10.5	25 32.1	5 8 7			
11.5	22 49.2	5 17 48	0.47006	0.31049	1.5
12.5	20 10.0	5 27 21			
13.5	17 31.6	5 36 16	0.47264	0.31838	1.4
14.5	15 3.0	5 46 2			
15.5	12 35.1	5 55 10	0.47521	0.32653	1.4
16.5	10 10.9	6 4 10			
17.5	7 50.5	6 13 1	0.47776	0.33488	1.3
18.5	5 33.8	6 21 44			
19.5	3 20.8	6 30 18	0.48031	0.34341	1.2
20.5	19 1 11.5	6 38 43			
21.5	18 59 5.9	6 47 0	0.48285	0.35207	1.2
22.5	57 4.0	6 55 8			
23.5	55 5.6	7 3 7	0.48538	0.36084	1.1
24.5	53 10.8	7 10 58			
25 5	51 19.5	7 18 40	0.48789	0.36969	1.1
26.5	49 31.6	7 26 14			
27.5	47 47.2	7 33 39	0.49039	0.37859	1.0
28.5	46 6.2	7 40 56			
29.5	44 28.4	7 48 5	0.49288	0.38751	0.9
30.5	42 53.9	7 55 6			
31.5	41 22.6	8 1 58	0.49536	0.39643	0.9
Sept. 1.5	39 54.5	8 8 43			
2.5	38 29.4	8 15 20	0.49783	0.40533	0.9
3.5	37 7.3	8 21 49			
4.5	35 48.2	8 28 11	0.50029	0.41419	0.8
5.5	34 32.0	8 34 26			
6.5	33 18.7	8 40 33	0.50274	0.42299	0.8
7.5	32 8.1	8 46 33			
8.5	31 0.2	8 52 26	0.50517	0.43172	0.7
9.5	29 55.0	8 58 12			
10.5	28 52.4	9 3 51	0.50759	0.44037	0.7
11.5	27 52.3	9 9 24			
12.5	26 54.6	9 14 50	0.51000	0.44893	0.7
13.5	25 59.4	9 20 10			
14.5	25 6.6	9 25 23	0.51240	0.45740	0.6
15.5	24 16.1	9 30 31			
16.5	23 27.8	9 35 32	0.51479	0.46575	0.6
17.5	18 22 41.7	−9 40 27			
Sept. 18.5	18 21 57.8	−9 45 16	0.51717	0.47399	0.6
19.5	21 16.0	9 50 0			
20.5	20 36.3	9 54 38	0.51954	0.48210	0.5
21.5	19 58.6	9 59 10			
22.5	19 22.8	10 3 37	0.52189	0.49009	0.5
23.5	18 49.0	10 7 59			
24.5	18 17.0	10 12 15	0.52423	0.49795	0.5
25.5	17 46.8	10 16 26			
26.5	17 18.4	10 20 33	0.52656	0.50567	0.5
27.5	16 51.8	10 24 34			
28.5	16 26.8	10 28 31	0.52888	0.51326	0.5
29.5	16 3.5	10 32 22			
30.5	15 41.8	10 36 9	0.53119	0.52070	0.4
Oct 1.5	15 21.6	10 39 51			
2.5	15 3.0	10 43 28	0.53349	0.52800	0.4
3.5	14 45.8	10 47 1			
4.5	14 30.1	10 50 30	0.53577	0.53515	0.4
5.5	14 15.8	10 53 54			
6.5	14 2.8	10 57 14	0.53805	0.54216	0.4
7.5	13 51.2	11 0 30			
8.5	13 40.8	11 3 41	0.54031	0.54902	0.4
9.5	13 31.7	11 6 48			
10.5	13 23.9	11 9 51	0.54256	0.55574	0.3
11.5	13 17.3	11 12 50			
12.5	13 11.8	11 15 44	0.54480	0.56231	0.3
13.5	13 7.4	11 18 35			
14.5	13 4.2	11 21 22	0.54704	0.56873	0.3
15.5	13 2.0	11 24 5			
16.5	13 0.9	11 26 45	0.54926	0.57501	0.3
17.5	13 0.8	11 29 21			
18.5	13 1.8	11 31 53	0.55147	0.58115	0.3
19.5	13 3.7	11 34 21			
20.5	13 6.5	11 36 46	0.55366	0.58714	0.3
21.5	13 10.2	11 39 7			
22.5	13 14.9	11 41 25	0.55585	0.59298	0.3
23.5	13 20.5	11 43 39			
24.5	13 26.9	11 45 49	0.55802	0.59868	0.3
25.5	13 34.2	11 47 56			
26.5	13 42.2	11 49 59	0.56018	0.60424	0.3
27.5	13 51.1	11 51 59			
28.5	14 0.7	11 53 56	0.56234	0.60966	0.2
29.5	14 11.1	11 55 50			
30.5	14 22.1	11 57 40	0.56448	0.61494	0.2
Oct. 31.5	14 33.8	11 59 27			
Nov. 1.5	18 14 46.2	−12 1 10	0.56662	0.62007	0.2

Troy, *N.Y.*, 1889 *May* 31.

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SYSTEMATIC CORRECTIONS OF STAR-POSITIONS NEAR THE EQUATOR, WITH A NOTE ON THE CONSTANTS OF SOLAR MOTION.

BY LEWIS BOSS.

It is now in order to ascertain the systematic corrections, c_2 and c'_2, necessary to reduce the positions and proper motions of the *Fundamental-Catalog* to the adopted normal system. In the work already cited, NEWCOMB gives the correction for BESSEL's reduction of BRADLEY's observations as $-0^s.01$, neglecting small periodic terms which are evidently of no practical importance.

The new reduction by AUWERS has been most exhaustively compared by him with that of BESSEL: and the relation between the two is of a somewhat complicated form. It may be simplified for the present purpose by considering only that portion of BRADLEY's catalogue which lies within the limits of the Albany zone. In this region the mean difference, Auwers—Bessel, is $+0^s.053$; hence we have, for Newcomb—Auwers's Bradley, $-0^s.063$. (For all the stars south of the Greenwich zenith AUWERS finds $+0^s.041$ for Auwers—Bessel, and therefore Newcomb—Auwers's Bradley $= -0^s.051$.) In computing the positions of his *Fundamental-Catalog* AUWERS began with the Pulkowa catalogue for 1865 as a basis, having first corrected the right-ascensions to NEWCOMB's normal system. For stars near $+3°$ of declination we have, accordingly, as the correction of the *Fundamental-Catalog* to the adopted normal system,

$$c_2 = +0^s.0005\,(T-1865).$$

I have elsewhere* found for declination and proper-motion as the relation,

NORMAL—AUWERS'S FUNDAMENTAL CATALOG.

δ	$\Delta\delta$	$\Delta\mu$	
°	″	″	
−10	+0.30	−0.012	$(T-1875)$
0	+0.25	−0.014	
+10	+0.18	−0.012	
+20	+0.10	−0.011	
+30	+0.04	−0.015	
+40	+0.01	−0.012	
+50	−0.03	−0.005	
+60	−0.06	0.000	
+70	−0.08	+0.003	
+80	−0.10	+0.004	

But in order to determine the correction more especially for the region under discussion, I have made a comparison between my standard declinations and proper-motions and those of the *Fundamental-Catalog* of AUWERS, confining the discussion to stars situated between the parallels of +15° and −10° of declination, with the following result.

R.A.	Stars	$\Delta\delta$	$\Delta\mu'$
h		″	″
0	11	+0.25	−0.0097
4	9	+0.18	−0.0093
8	5	+0.13	−0.0198
12	5	+0.10	−0.0152
16	8	+0.24	−0.0139
20	14	+0.26	−0.0126
General means	52	+0.217	−0.0126

There is here some evidence favoring the hypothesis of periodicity in R.A. for the values of $\Delta\delta$ and $\Delta\mu$; but I have shown in the article previously cited that such a term is probably insensible when all declinations are taken into account. I therefore adopt for the correction in declination, Normal—Auwers (F.C.),

$$c'_2 = +0''.217 - 0''.0126\,(T-1875).$$

Adding these values of c_2 and c'_2 to the quantities in Table V, we have the final values of c and c' for the various catalogues, so far as these result from the comparisons with the Special Catalogue. It will be desirable in some cases, however, to derive them from other sources also. If we disregard the possible error of STRUVE's precession-coefficients, as well as the effects of parallactic motion, neglected proper-motion and other neglected secular terms which may affect the positions of stars when transferred from one epoch to another, we may obtain values of c and c' from Table III by applying to it the systematic correction due to the Albany catalogue for 1880.5. From the foregoing values of c_2 and c'_2 this becomes: $+0^s.008$ in R.A., and $+0''.15$ in Decl.

NEWCOMB has investigated the correction, c, to his system required by the right-ascensions of PIAZZI and STRUVE (1830); and I have elsewhere (*Decl. Fixed Stars*) computed c' for these authorities. The corrections for D'AGELET, LALANDE, BESsel and Argelander (1855), might also be inferred in whole or part by the values of c_0 and c'_0 for the standard catalogues upon which they are based; but these values differ very decidedly from those otherwise ascertained, for D'Agelet and Bessel at least, and for Argelander the standard catalogue was not the same throughout the observations. In the older zone-observations we have little independent assurance that the systematic peculiarities of the respective standard catalogues were reproduced in the observations for which they served as a basis. One reason for this is that the individual star-positions of these standard catalogues were often subject to very material errors; but a much more effective source of error arises from the methods of observation of zone-stars, in the case of Bessel's zones at least.

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* Proceedings of the Am. Assoc. Adv. Sci., Saratoga Meeting, 1879, pp. 119–121.

The value of c_0 and c'_0 may be derived for the catalogue of Schjellerup through the comparison with the Armagh catalogue for 1840, which Schjellerup gives in the introduction to his catalogue. Adopting the quantities resulting from 294 differences in R.A., and 287 in δ (p. xx of the Int.), we have for Armagh—Schjellerup: $\Delta\alpha = +0^s.050$, $\Delta\delta = +0''.19$. Newcomb finds $+0^s.020$ as the correction to right-ascensions, and for the region $+15°$ to $-15°$ I find (*Decl. Fixed Stars*, p. 177) $-0''.95$ as the correction to the declinations of Robinson's Armagh catalogue. Thus we have:

Normal—Schj. (through Armagh catalogue):

$$c_0 = +0^s.070\,;\ c'_0 = -0''.76.$$

The positions of the *British Nautical Almanac* served Schjellerup as a standard catalogue. I find for 58 stars of the *Nautical Almanac* for 1863 between $+15°$ and $-15°$ of declination: $c_0 = +0^s.061$; $c'_0 = +0''.07$. The value of c'_0 is at variance with other determinations of this quantity. To c_0 might be appended the periodic term which Newcomb found for the Greenwich right-ascensions for 1840, $-0^s.03 \sin\alpha + 0.01 \cos\alpha$, since it is consistent with the individual mean values of c_0 which I have found. But the constant, $+0^s.061$, though it agrees well with that which results from comparison with the Special Catalogue (Table V) and also with the foregoing derived through Armagh, does not accord well with the corrected mean to be hereafter derived from Table III, which is $+0^s.040$. It may be remarked that the differences for c_0 from the 58 stars range in value from $-0^s.02$ to $+0^s.19$; so that one cannot demand critical agreement between results for systematic correction. From the mean of all values of $\Delta\alpha$ in Table III, I derive

$$\begin{aligned} &+0^s.032\ +0^s.001 \sin\alpha\ +0^s.020 \cos\alpha \\ &\qquad -0^s.042 \sin 2\alpha - 0^s.016 \cos 2\alpha \end{aligned}$$

but so much depends upon the choice of standard stars which Schjellerup may have happened to make on each night, that the periodic part of this expression cannot be regarded as of much significance.

On the principles already prescribed the several values of c_0 and c'_0 are computed, and are here collected for purposes of comparison.

Table VI.

	Through	c_0		c'_0	
		s	s °	″	″ °
D'Agelet	Sp. Cat. Tab. I and II	+0.09		—0.4	
Piazzi	Sp. Cat. Tab. I and II	+0.12		—1.76	$+0.39 \sin(\alpha+339)$
	Direct	+0.08		—1.40	$+0.56 \sin(\alpha+341)$
Lalande's zones	Sp. Cat. Tab. I and II	+0.10	$+0.018 \sin(\alpha+201)$	—1.24	$+0.38 \sin(\alpha+319)$
	Alb. Cat. Tab. III	+0.06	$+0.072 \sin(\alpha+\ 94)$	—3.05	$+0.81 \sin(\alpha+275)$
Bessel's zones	Sp. Cat. Tab. I and II	—0.16	$+0.101 \sin(\alpha+291)$	+0.78	$+1.32 \sin(\alpha+227)$
	Alb. Cat. Tab. III	—0.15	$+0.046 \sin(\alpha+300)$	—0.30	$+1.17 \sin(\alpha+250)$
Struve, 1830	Sp. Cat. Tab. I and II	0.00		—0.42	
	Direct	—0.014		—0.42	
Rümker	Sp. Cat. Tab. I and II	+0.06		+0.52	$+0.70 \sin(\alpha+282)$
Argelander (Bonn)	Alb. Cat. Tab. III	—0.06	$+0.026 \sin(\alpha+\ 38)$	—1.01	$+0.27 \sin(\alpha+309)$
	Direct (Bonn, 1866)	–		—0.28	$+0.34 \sin(\alpha+334)$*
Schjellerup	Sp. Cat. Tab. I and II	+0.07		—0.26	
	Alb. Cat. Tab. III	+0.040		—0.66	
	Armagh	+0.070		—0.76	
	Naut. Almanac	+0.064	$-0.03 \sin\alpha + 0^s.01 \cos\alpha$	+0.07	

In deciding upon the adopted values of the corrections, c_0 and c'_0, from the preceding table, the preference will be given to the results from Tables I and II whenever the comparisons on which they are founded appear sufficiently numerous. The comparatively large differences between the results from Tables I and II, as compared with those from

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* This is the correction which I have found for Bonn, 1866 (*Ast. Nach.* 1719), and it is not strictly comparable with that which is required for the general run of observations in Volume VI of the Bonn Observations.

Table III, appear to point to some systematic source of difference, which will be investigated hereafter. The values of the constant terms of c'_0 from Table III may be permitted to have some weight after they are corrected by

$$-0''.0181\,(T-1880.5).$$

(where T is the epoch of the catalogue in question for reasons which will be explained hereafter.

Following is the table of

Finally Adopted Systematic Corrections. Table VII

Authority	Epoch	c_0	c'_0
		s	″
D'Agelet	1783	+0.09	—0.40
Piazzi	1800	+0.12	—1.60 +0.50 sin(α+340°)
Lalande's zones	1796	+0.09	—1.35 +0.50 sin(α+340°)
Bessel's zones	1823	—0.16 +0.101 sin(α+291°)	+0.80 +1.32 sin(α+227°)
Struve, 1830	1830	—0.014	—0.42
Rümker	1840	+0.06	+0.52 +0.70 sin(α+282°)
Argelander (Bonn)	1859	—0.06	—0.45 +0.30 sin(α+320°)
Schjellerup	1863	+0.06	—0.30
Albany	1880.5	+0.008 —0.0087 (M—4) —0.00116 (M—4)^2	+0.15

The application of the above corrections is intended to bring the various catalogue-determinations near +3° (say 0° to +6°) of declination into systematic harmony with the star-positions of the *American Ephemeris* for 1881, which are founded upon the investigations of Newcomb for right-ascension, and of Boss for declination. They may be regarded as applying sufficiently well throughout the region +15° to —15° of declination.

The discrepancy in Table VI between the corrected results from Tables I and II and those from Table III, is sufficiently great to excite attention: and although the quantities from Tables I and II depend upon a small number of comparisons, still these differences are evidently larger than those which could readily be ascribed to casual errors of observation. We have:

c_0 and c'_0 from Comparison with Albany *minus* the same from Comparison with the Special Catalogue. Table VIII.

	Δc_0	$\Delta c'_0$
	s	″
For Lalande's zones	—0.04 +0.080 sin(α+ 81°)	—1.80 +0.60 sin(α+ 69°)
Bessel's zones	+0.01 +0.056 sin(α+104°)	—1.08 +0.51 sin(α+345°)
Schjellerup	—0.03	—0.34

So far as the constant part of c_0 and the periodic part of c'_0 is concerned the differences when compared with each other appear to follow no readily discoverable law. The preponderance of the minus quantities in the constant part of Δc_0 might arise either from error in Newcomb's system, from personal equation dependent on magnitude, or from a very small error in Struve's value of m, but none of them is large enough to excite much curiosity.

But in reference to the periodic part of the values of Δc_0 and the constant part of $\Delta c'_0$ the case is different, since there is a general resemblance between the successive quantities which cannot fail to attract attention. The constant part of the differences for $\Delta c'_0$ might be attributed to error in the normal system; but it is hardly supposable that any relatively important part of them could have arisen from this source. The only other explanation which readily suggests itself is that the periodic part of Δc_0 and the constant part of $\Delta c'_0$ arises from the parallactic effect of solar motion. This hypothesis we will proceed to investigate.

The stars from which these differences arise are on the one side those whose proper-motions are known and taken into account, and the values of c_0 and c'_0 from them may be supposed to be free from any secular parallactic effect, for reasons which do not appear to require special demonstration. On the other hand, Table III was constructed through the comparison of star-positions from the respective authorities with the corresponding ones of the Albany catalogue: and the former were brought down to the epoch of the latter without correction for proper-motion in any case. The stars in question here are for Lalande, only those which he designated as of the magnitude 7–8 (*i.e.* $7^M.5$) or fainter, and whose proper-motion appears to be within the probable error of determination, — probably the mean magnitude is not far from $8^M.5$; for Bessel they are also stars whose proper-motions cannot safely be evaluated, and which he estimated to be of the magnitude 8–9 (*i.e.* $8^M.5$) or fainter (mean probably $8^M.9$ to $9^M.0$): and for Schjellerup (for the purposes of the present discussion) those stars which in the Albany catalogue are estimated to be of magnitude $8^M.7$ or fainter. The average magnitude of all the stars of the second class may therefore be taken as $8^M.8$, to $8^M.9$, or roughly $9^M.0$.

If now we designate by A and D respectively the right-ascension and declination of the apex of solar motion, and by M the secular parallactic effect for the sun's motion for stars at the average distance of ninth-magnitude stars, and upon the great circle 90° from the apex of solar motion, we shall have for the apparent average parallactic effect upon ninth-magnitude stars situated upon the equator (μ denoting the R.A., and μ' the Decl. coordinate of that effect), the following expressions:

$$\mu = M\cos D\sin(\alpha - A)\,; \quad -\mu' = M\sin D.$$

The average declination of the stars in the Albany zone is +3°, and they may therefore be considered without material error, as if situated upon the equator; and for convenience this assumption will be adopted.

The average interval of observation between the positions of LALANDE's zones and the Albany catalogue is about 84 years; that for BESSEL's zones, about 58 years; and for SCHJELLERUP, 18 years. Therefore we have for the values of μ and μ':

	Wt.	$\mu =$		$\mu' =$
From LALANDE;	1	$M\cos D(\sin\alpha - A) = +1''.41$	$\sin(\alpha - 279^\circ)$	$M\sin D = +2''.11$
From BESSEL;	2	$= +1.45$	$\sin(\alpha - 256)$	$= +1.86$
From SCHJELLERUP;	0	–	–	$= +1.89$
Adopted means:		$M\cos D = +1.43$		$M\sin D = +1.95$

The value of A is given directly, and may be taken as 264° for the weighted mean of LALANDE and BESSEL. The result for $M\sin D$, for BESSEL, depends upon 3436 comparisons (Table III), and that for LALANDE upon 1687. Considering also the greater weight of BESSEL's declinations, the second of the above values of $M\sin D$ is entitled to the weight 2 as against 1 for that from LALANDE; while, owing to the short interval and small number of stars upon which the value for SCHJELLERUP is founded, it is neglected, though it might have received the weight 0.2, which would have left the adopted mean practically uninfluenced.

Solving now for the values of M and D we obtain:

$$M = 2''.42\,; \quad A = 264^\circ\,; \quad D = +\,54^\circ.$$

The value of A, though from observation extremely uncertain in the present instance, happens to be very near the average of modern determinations, but the value of D is decidedly greater than that resulting from the general average of modern research.* Since the value of M is found from stars whose proper motions are so small as to escape certain detection with the available material, it is so far as that argument goes too small. L. STRUVE finds ($q =$) $M = 4''.36$ for the average sixth-magnitude star, which becomes by an extension of the table on page 7 of his memoir (which gives $\rho = 3.33$ for magnitude 9.0) $1''.45$ for a ninth-magnitude star. DUNKIN obtained $5''.22$ for sixth-magnitude stars, and consequently $1''.74$ for stars of the ninth magnitude. But if L. STRUVE had reduced the two catalogues which form the basis of his work to the present system of the *American Ephemeris* the value of his "q" (M) would have been materially greater, as would also his value of D.

If now we reverse the process and compare the observed values of Δc_0 and $\Delta c'_0$, in Table VIII, with L. STRUVE's compiled values ($A = 266^\circ.7$; $D = +31^\circ.0$), and with BISCHOF's determination ($A = 280^\circ.7$; $D = +48^\circ.5$), and adopt for M the value $2''.42$ as here found, we shall have:

	For Δc_0 Observed	BISCHOF	L. STRUVE	$\Delta c'_0$ Observed	BISCHOF	L. STRUVE
Lalande's zones	$+0^s.080\sin(\alpha - 279^\circ)$	$+0^s.090\sin(\alpha - 285^\circ.7)$	$+0^s.117\sin(\alpha - 266^\circ.7)$	$-1''.81$	$-1''.53$	$-1''.05$
Bessel's zones	$+0.056\sin(\alpha - 256)$	$+0.062\sin(\alpha - 285.7)$	$+0.080\sin(\alpha - 266.7)$	-1.08	-1.05	-0.72
Schjellerup	– –	– –	– –	-0.34	-0.33	-0.22

The agreement of the observed and computed values is, perhaps, quite as good as could have been expected, but is manifestly much better for BISCHOF's numbers than for STRUVE's. This may be due to the fact that the average magnitude of the stars employed by STRUVE is very much greater than that of the stars upon which BISCHOF's investigation is founded, as well as to the more important fact that the proper motions used by the latter are on the average more than twice as great as those employed by STRUVE. A part of the above discrepancies may also easily be due to error in the fundamental system, but I regard it as quite improbable that the systematic error in δ can alter so much as $1''.0$ per century, or, in fact, much more than half that quantity. In fact, both Δc_0 and $\Delta c'_0$ are necessarily subject to comparatively large probable errors; since one term of the comparison depends on only 212 observations in R.A. and 219 in Decl. for LALANDE, 153 in R.A. and 152 in Decl. for BESSEL, and only 34 in R.A. and 32 in Decl. for Schjellerup; and the other is very markedly influenced by the constant errors of the zones. The results can, therefore, be regarded to be quite as satisfactory as could have been expected, and on the whole appear to warrant the following conclusions:

---

* In recent years we have had the investigation of Dr. Johann BISCHOF, who obtained from 480 proper-motions, mostly greater than $0''.2$ annually, and chiefly of telescopic stars, the results, $A = 285^\circ.7$, $D = +\,48^\circ.5$; and, by another method of discussion, $A = 290^\circ.8$, $D = +\,43^\circ.5$. Dr. Ludwig STRUVE has recently obtained from a discussion of 2509 stars observed by BRADLEY (AUWERS) and compared with the new Pulkowa catalogue, $A = 273^\circ\,21'$; $D = +\,27^\circ\,19'$. He also finds for the general mean of modern determinations, excluding those by W. HERSCHEL, GAUSS and AIRY: $A = 266^\circ.7$; $D = +\,31^\circ.0$. Since L. STRUVE's determination includes nearly all the material used by his predecessors, and BISCHOF's discussion nearly all available material not used by L. STRUVE, it seems probable that a more accurate mean result might have been derived by taking the simple mean between these two determinations. Furthermore, L. STRUVE's result depends upon the new reduction of BRADLEY, and BISCHOF's upon BESSEL's reduction,—though, since the latter employed chiefly stars of comparatively large proper-motion, his result would be less influenced by the systematic errors of catalogues. The mean between these two results is: $A = 278^\circ.3$, $D = +37^\circ.9$.

1°. It does not appear probable from this discussion that any important correction to Struve's coefficients of precession is required.*

2°. The effect of secular parallactic motion is well marked among stars of the ninth-magnitude; and in cases where it is desired to reduce from one epoch to another the position of a ninth-magnitude star, for which exist no adequate means of determining the proper-motion, it appears advisable to allow 2″.4 for this motion, which for stars situated only a few degrees from the equator may be taken as:

$+0^s.107 \sin(\alpha+267°)$ for R.A., and $-1''.81$ for Decl,†

these quantities to be multiplied by $\frac{1}{100}(T'-T)$ when it is desired to reduce a position from the epoch T to T'.

3°. Systematic corrections for +3° of declination, computed from comparison of catalogues with the system of the *American Ephemeris* (1881 and later volumes), are reasonably consistent with the employment of Struve's precessions, combined with the results of modern research as to the coordinates of solar motion.

4°. A detailed study of the zone-observations of Lalande and Bessel points to the conclusion that the value of the positions can be very greatly increased, especially for the purposes of general discussion, whenever it becomes possible to construct standard star-positions for the respective epochs in sufficient number to permit of a satisfactory examination of the systematic peculiarities of each separate zone as reduced by Von Asten's and Luther's tables.

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* It might be inferred that m and n each require a correction of of about $-0''.005$.

† This is based on L. Struve's mean value of A, Bischof's value of D, and upon the adoption of 2″.4 as the constant of parallactic motion for a ninth-magnitude star, though the latter relates to a star one or two-tenths of a magnitude brighter. These constants are chosen simply because they give a fairly good representation of observation.

OBSERVATIONS OF FAYE'S COMET,

By E. E. Barnard, Astronomer of the Lick Observatory.

The following observations of Faye's comet have been made with the filar-micrometer of the 12-inch equatorial. It was very difficult to observe, and has required the utmost care and patience throughout.

The comet was easily found the same night that the despatch announcing its discovery at Nice was received, and I think it could have been observed here probably from one to two months earlier had its place been known.

Absence on our eclipse expedition prevented observations during most of December and January, and work on the photographic results of that expedition has delayed the preparation of the observations for printing until now.

Several attempts to refind the comet after the February moon proved futile, as no ephemeris was at hand, and later, when an ephemeris was received, our bad weather had set in and it was not again seen.

When first looked for, on February 4, the comet could not be found at 11^h, but upon very close examination a 9^M star — used later for comparison — was seen to be apparently nebulous, a faint glow almost symmetrically surrounding it. At $11^h\ 15^m\ 54^s$, Mt. Hamilton M.T., by careful examination, the center of this nebulosity was estimated as certainly not over 2″ *following* the star, which will give the comet's place with accuracy. Returning to this place later at night the comet was seen to have left the star, and was some little distance n.p., where it was observed with the micrometer.

In the observation of August 10, the comet was carefully watched until it and the comparison-star were exactly on the same parallel, as bisected by the wire, this was then corrected for motion to the epoch of $\Delta\alpha$.

The smallness of the comet has been quite striking. It was at no time over 30″ in diameter — a little brighter in the middle, its light being more like one of the small indefinite faint nebula, than that of a comet. It was brightest and easiest to observe about the first part of December.

The comparison-star of February 4 was inadvertently compared with the star DM. +2°1734, instead of W.B. VII 983, as was at first supposed.

In *A.N.* 2859, in the Nice observations, the seconds of right-ascension for August 14 should be 59, instead of 19, as will be seen by applying the $\Delta\alpha$ to the star's place.

The value of a revolution of the micrometer-screw adopted and used in the observations is 14″.057 ± 0″.004. The observed $\Delta\alpha$ have been recorded by "eye and ear."

In our micrometer there are but two spider threads, and in observing, a set of $\Delta\delta$ was made, and the micrometer revolved 90°, and a set of $\Delta\delta$ taken over the two wires, the micrometer revolved back and another set of $\Delta\delta$ made. With care, the mean of the times for the two sets of $\Delta\delta$ almost always agreed with the mean of the times for $\Delta\alpha$ to one minute. These were then corrected by the known motion to the same epoch.

The observations have been corrected for differential refraction. In the list of comparison-stars, the columns headed $\Delta\alpha$ and $\Delta\delta$, give the comparisons, comparison-star — the star with which it was compared.

Mt. Hamilton, 1889 *May* 31.

FILAR-MICROMETER OBSERVATIONS OF FAYE'S COMET,

MADE WITH THE 12-INCH EQUATORIAL OF THE LICK OBSERVATORY,

By E. E. BARNARD.

1888 Mt.Hamilton M.T.	✱	No. Comp.	☄ — ✱ Δα	☄ — ✱ Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
d h m s			m s	′ ″	h m s	° ′ ″		
Aug. 10 15 1 48	1	8	—0 27.03	—0 0.8	5 4 7.97	+19 58 12.0	n9.672	0.622
11 15 18 41	2	9 , 5	—1 41.50	+0 9.9	5 6 52.79	+19 55 49.4	n9.657	0.604
12 15 15 59	2	16 , 12	+0 59.89	—2 23.0	5 9 34.21	+19 53 12.0	n9.660	0.609
13 15 12 32	3	7 , 1	—1 50.16	—0 5.8	5 12 15.5	+19 50.4	n9.651	0.609
14* 14 59 38	4	7 , 5	+0 31.81	+5 26.6	5 14 55.01	+19 47 24.3	n9.669	0.619
15 15 15 29	4	8 , 4	+3 16.77	+2 24.3	5 17 37.01	+19 44 22.1	n9.651	0.600
16 15 44 51	5	10 , 3	+0 27.40	+1 2.4	5 20 19.9	+19 42.2	n9.624	0.563
17 15 30 27	6	31 , 4	—0 10.88	—3 36.6	5 22 58.6	+19 37.8	n9.638	0.588
18 15 38 29	7	10 . 4	+0 33.51	+0 27.3	5 25 37.61	+19 33 22.6	n9.628	0.586
Oct. 7 16 4 0	8	12 , 5	—0 3.66	+3 54.3	7 20 31.7	+12 38.4	n9.401	0.589
8 16 33 34	9	4 , 3	—0 20.67	+5 50.8	7 22 14.31	+12 27 56.5	n9.283	0.582
15 16 46 50	10	16 , 5	+0 9.46	+6 42.1	7 33 8.22	+11 8 10.1	n9.121	0.593
Nov. 4 16 4 42	11	14 , 6	+9 41.33	—4 9.9	7 58 48.72	+ 7 10 49.8	n9.045	0.648
10 15 2 31	12	12 , 6	—1 3.65	—5 35.5	8 4 3.12	+ 6 2 50.8	n9.276	0.666
28 12 59 28	13	10 , 7	—2 36.37	—0 34.1	8 12 18.02	+ 3 0 24.1	n9.477	0.705
Dec. 1 12 46 11	14	12 , 6	—0 7.30	—2 36.8	8 12 32.76	+ 2 34 27.4	n9.480	0.708
2 12 31 21	15	6 , 5	—0 41.66	—1 35.1	8 12 32.92	+ 2 26 53.5	n9.599	0.712
5 12 22 30	16	8 , 6	—1 18.39	+6 43.1	8 12 22.44	+ 2 3 47.9	n9.498	0.714
6 12 9 29	16	8 , 3	—1 26.51	—0 26.2	8 12 14.34	+ 1 56 38.4	n9.517	0.713
1889								
Jan. 21 9 51 3	17	6 , 6	+0 26.66	+6 15.0	7 41 53.80	+ 1 17 39.3	n9.318	0.716
22 10 18 17	18	16 , 6	+0 16.31	+2 58.3	7 41 7.00	+ 1 23 0.0	n9.149	0.713
23 9 42 54	18	14 , 8	—0 26.96	+8 1.6	7 40 23.75	+ 1 28 3.0	n9.307	0.714
25 10 20 46	19	10 , 7	—1 6.05	—0 48.4	7 38 55.52	+ 1 39 21.1	n9.057	0.711
26 11 2 44	20	12 , 9	—0 55.41	+0 39.7	7 38 13.32	+ 1 45 25.4	n8.279	0.710
27 12 39 37	21	12 , 6	+0 24.13	—0 9.0	7 37 29.66	+ 1 51 59.7	9.262	0.710
Feb. 2 10 53 28	22	12 , 6	—0 16.44	—2 30.4	7 33 57.80	+ 2 29 41.1	7.903	0.702
3 10 9 51	22	12 . 9	—0 45.94	+4 7.2	7 33 28.29	+ 2 36 18.6	n8.851	0.700
4 14 36 18	23	10 , 5	—0 3.13	+1 11.6	7 32 53.2	+ 2 44.4	9.616	0.713
5 12 22 46	24	10 , 7	—0 6.47	+0 35.4	7 32 28.3	+ 2 50.5	9.358	0.701
7 13 53 38	25	6 , 4	—1 28.26	—0 47.5	7 31 35.99	+ 3 4 58.2	9.571	0.708

* The observation of the 14th of August made with a ring-micrometer.

Mean Places for 1888.0 of Comparison-Stars.

✱	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	5 4 34.48	+0.52	+19 58 15.4	—2.6	10ᴹ comp. with W.B. V, 168
2	5 8 33.77	{ +0.52 +0.55 }	+19 55 42.1	{ —2.6 —2.6 }	W.B. V, 168
3	5 14 5.1	+0.55	+19 50.5	—2.6	DM. +19°901.
4	5 14 19.63	{ +0.57 +0.61 }	+19 42 0.3	{ —2.6 —2.5 }	½(Grant 1302 +W.B. V, 345)
5	5 19 51.9	+0.62	+19 41.2	—2.6	DM. +19°926
6	5 23 8.9	+0.64	+19 41.5	—2.5	DM. +19°937
7	5 25 3.44	+0.66	+19 32 57.8	—2.5	Rümker 1452
8	7 20 34.2	+1.23	+12 34.6	—2.8	DM. +12°1546
9	7 22 33.57	+1.41	+12 22 8.7	—3.0	W.B. VII 622
10	7 32 57.19	+1.57	+11 1 31.9	—4.2	W.B. VII 955
11	7 58 5.42	+1.97	+ 7 15 4.5	—4.8	Comp. with B.B. +7°1903
12	8 5 4.63	+2.14	+ 6 8 31.8	—5.5	Comp. with W.B. VIII, 8
13	8 14 51.82	+2.57	+ 3 1 5.6	—7.4	Lal. 16341
14	8 12 37.40	+2.66	+ 2 37 12.1	—7.9	Comp. with W.B. VIII. 233
15	8 13 11.90	+2.68	+ 2 28 36.7	—8.1	Comp. with B.B. +2°1933
16	8 13 38.05	{ +2.78 +2.80 }	+ 1 57 13.3	{ —8.5 —8.7 }	Comp. with W.B. VIII, 333

Mean Places for 1889.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	s	
17	7 41 26.56	+0.58	+ 1 11 29.4	—5.3	W.B. VII, 1205
18	7 40 50.13	+0.56 +0.58	+ 1 20 7.0	—5.4 —5.6	Comp. with W.B. VII. 1205
19	7 40 0.98	+0.59	+ 1 40 15.4	—5.9	Comp. with B.B. +1 1907
20	7 39 8.14	+0.59	+ 1 44 51.7	—6.0	Comp. with *19
21	7 37 4.94	+0.59	+ 1 52 11.8	—6.1	$\frac{1}{5}$(W.B. VII, 1080 +4 Schj. 2803)
22	7 34 13.63	+0.61 +0.60	+ 2 32 18.1	—6.6 —6.7	Comp. with W.B. VII. 972
23	7 32 55.7	+0.59	+ 2 43.3	—6.7	Comp. with DM. +2°1734
24	7 32 34.2	+0.58	+ 2 50.0	—6.8	Comp. with *23
25	7 33 3.68	+0.57	+ 3 5 52.7	—7.0	Comp. with W.B. VII, 886

The decl. of Weisse's Bessel VII, 1633, requires a correction of —10″.

FILAR-MICROMETER OBSERVATIONS OF COMET *e* 1888,

MADE AT THE HAVERFORD COLLEGE OBSERVATORY.

1888–9 Haverford M.T.	*	No. Comp.	☄ — * Δα	☄ — * Δδ	☄'s apparent α	☄'s apparent δ	log *p*Δ for α	log *p*Δ for δ	Obs.
d h m s			m s	′ ″	h m s	° ′ ″			
Dec. 6 8 11 26	1	15 , 5	— 2 50.18	—4 6.6					B
9 5 15	1	12 , 4	— 3 1.76	—4 22.4					Lw
13 8 27 25	2	9 , 2	— 5 56.82	—5 26.2	1 12 48.31	—7 35 14.4	*n*8.910	0.812	B
14 8 6 9	2	6 , –	— 9 59.12		1 8 46.01		*n*8.803		L
8 6 9	3	6 , 2	—10 26.90	—3 23.5	1 8 16.23	—7 37 19.7	*n*8.803	0.813	L
Jan. 2 8 39 23	4	– , 4		—9 28.8		—7 14 21.3	9.521	0.876	T
3 8 27 27	4	15 , 5	— 3 30.63	—5 3.6	0 13 48.88	—7 9 56.1	9.521	0.876	B

Mean Places for 1888.0 and 1889.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place.	Authority
	h m s	s	° ′ ″	″	
2	1 18 42.67	+2.46	—7 29 57.3	+ 9.1	Gould Gen. Catal. 1330
3	1 19 10.67	+2.46	—7 34 5.1	+ 8.9	Weisse's Bessel I, 283
4	0 17 20.64	—1.13	—7 4 41.9	—10.6	Schjellerup 122

Observers. — R. C. Banes, D. C. Lewis, F. P. Leavenworth, L. W. Todhunter.

ON AN ERROR IN THE COMPUTATION OF THE SOLAR PARALLAX.

By WILLIAM HARKNESS.

Prof. Newcomb has kindly called my attention to an error in the computation of the solar parallax, which arises from inadvertently confusing the mass of the earth with the combined mass of the earth and moon, and which exists not only in my paper, published in the last number of this Journal, but also in the writings of LeVerrier (*Comptes Rendus*, T. LXXV, p. 165), and others. In computing the perturbations of the planets the action of the moon is always merged in that of the earth, and therefore the quantity usually called the mass of the earth is in reality the combined mass of the earth and moon; but in the equation

$$\text{Solar parallax} = [2.784\,931]\sqrt[3]{(\text{mass of } Earth)} \qquad (A)$$

the moon has no part, and the mass entering it is that of the earth alone. As the so-called mass of the earth given in my article was obtained from perturbations of the planets, it is really the sum of the masses of the earth and moon. If we assume the mass of the moon to be $\frac{1}{81}$ of that of the earth, the mass of the earth alone will be

$$0.000\,003\,005\,097 \times \frac{80.5}{81.5} = 0.000\,002\,968\,225$$

with which equation (A) gives for the solar parallax 8″.759, instead of 8″.795 as erroneously stated on page 15.

Washington, D.C., 1889 *June* 4.

THE POSITION OF THE WASHINGTON 26-INCH REFRACTOR, 1876–1889.

BY PROF. A. HALL.

The building of large telescopes has become so common that it may be interesting to see how the 26-inch refractor of this Observatory remains in position. This instrument was partially dismounted in 1874, on account of some trouble with the declination-axis; and since its remounting no change or adjustment in the position of the instrument has been made. The circles were not provided with means of accurate and safe reading until 1876. These circles are read to $0'.2$ in declination, and to a second of time in right-ascension, and by estimation to a tenth of a second. A determination of the position of the instrument consists in the observation of two equatorial stars and of one polar star; each star being observed in both positions of the instrument. Such an observation gives, of course, three values of ξ, the rectangular coordinate of the pole of the instrument with respect to the pole of the heavens, and measured on the meridian; and two determinations of η, the coordinate perpendicular to the meridian. The values of ξ would be affected by the flexure, but I have found the flexure to be insensible. The following table gives the mean values of these coordinates. For some time past I have made only partial observations for position, sufficient to show that no essential displacement had taken place, but recently a complete determination was made.

Year.	Day	ξ	η
		′	′
1876	Dec. 13	—1.60	+0.28
1877	Jan. 9	—1.61	+0.27
1878	Jan. 3	—1.34	+0.47
1879	May 22	—1.40	+0.90
1880	Jan. 29	—1.26	+1.06
1880	Jan. 31	—1.31	+1.03
1881	May 10	—1.61	+0.23
1882	June 1	—1.54	—1.03
1882	Aug. 30	—1.56	+0.95
1883	May 18	—1.95	+0.17
1883	Dec. 29	—1.32	—0.62
1884	Dec. 3	—1.55	—0.01
1885	Aug. 26	—1.65	+0.89
1886	Dec. 10	—1.52	+0.74
1889	May 15	—1.83	+0.18

An error was suspected in the determination of June 1, 1882, but none could be found, and the resulting value of η has been retained. This coordinate shows some variations, which probably come from the lightness of the mounting in the direction perpendicular to the meridian. The other coordinate, ξ, has been, I think, remarkably steady; and this constancy testifies to the goodness of the stone and brick pier, and to the stiffness of the mounting in this direction. A description of the pier and mounting, by Prof. HOLDEN, will be found in our volume for 1874.

Naval Observatory, 1889 *May* 21.

ANOMALOUS TAIL OF COMET 1889 *I*.

BY E. E. BARNARD, ASTRONOMER OF THE LICK OBSERVATORY.

On June 3, at 3 A.M., while examining this comet with the $6\frac{1}{2}$ and 12-inch refractors, I was struck with a peculiar feature to which I wish to call attention. There was no trace of a tail *preceding* the comet. Directly *following*, however, was a distinct tail one degree in length, and some 2′ or 3′ broad. This was quite noticeable in both instruments. By moving the telescope, it was found that this tail was perfectly on a parallel of declination, the position-angle being 90°, and therefore pointing nearly towards the sun. The head was roundish, with an almost stellar nucleus of the 12th magnitude in an extended condensation: this latter having a position-angle of about 135°. The tail is best seen with a low power.

Mt. Hamilton, 1889 *June* 3.

NOTICE.

Mr. W. W. CAMPBELL of the Detroit Observatory, Ann Arbor, Mich., desires to give notice that he purposes computing a definitive orbit of comet 1888 *I* (*Sawerthal*), and asks that any yet unpublished observations of this comet be made public as soon as possible.

CORRIGENDUM.

No. 192, p. 191, col. 2. In the expression for rectangular coordinates in Mr. SCHAEBERLE's letter, substitute *u* for *v*.

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CORRIGENDUM.

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COMPARISON OF DR. GOULD'S REDUCTIONS OF MR. RUTHERFURD'S *PLEIADES* PHOTOGRAPHS WITH THE HELIOMETER-RESULTS.

BY W. L. ELKIN.

I have been very much interested in the appearance of Dr. GOULD's reductions of Mr. RUTHERFURD's photographs of stellar groups made over 20 years ago, but just published in Vol. IV, *Memoirs of the National Academy*. Photography has so come to the front lately as a means of research, and its powers placed so high, without, however, any very conclusive test of the accuracy attainable having been applied, or, at least, fully published, that the detailed publication of a rigid reduction of some plates seems to me especially opportune and valuable. It is true, we have had in the results given by Prof. THIELE on some *Praesepe* photographs of the Messrs. HENRY, and in the stellar parallax work of Prof. PRITCHARD at Oxford, evidence of the close agreement *inter se* of plates taken with the same instrument on one object, but, as far as I am aware, no comparison with the results of other methods of measurement of high accuracy, or attempt at detection of possible systematic error has been made. The comparison which Dr. GOULD gives at the close of the paper on the *Pleiades* with BESSEL's Königsberg Heliometer measures of the group does not quite afford the desired test, as at the time he wrote the relative motions in the cluster were not sufficiently well known to admit of their being taken into account; and furthermore, BESSEL's places as given by him are susceptible of considerable improvement by the use of a more correct value for the temperature coefficient of the Königsberg Heliometer. At present I think we are able to assign, for epochs intermediate between those of the Königsberg and Yale Heliometer work on the group, relative places of considerable accuracy to the *Pleiades* stars; and it has been to me of great interest to compare the photographic positions with those deduced with the Heliometer.

Dr. GOULD gives the relative distances and position-angles of the several stars, 40 in all, from *Alcyone*, and I have compared these in the following tables with values interpolated for the epoch 1867.0 from the revised Königsberg results for 1840, and the Yale measures for 1885. I have divided the stars into two classes, the first comprising the ten brighter stars, and the second the fainter ones: as for these two classes, the Heliometer coordinates are of somewhat different accuracy, and are not unlikely to be affected with different systematic error, which may possibly be the case with the photographic results also. For convenience, I have referred the photographic position-angles to the equator of 1885.0, but I have not included in the comparison two of Dr. GOULD's stars which were not observed at Königsberg, and the four which were only measured on one, two or three plates, viz.: Nos. 2, 8, 13 and 15.

COMPARISON OF PHOTOGRAPHIC AND HELIOMETER COORDINATES OF PLEIADES STARS.

I. DISTANCES OF BRIGHTER STARS FROM ALCYONE.

Star	Photographic Distance	Heliometer Distance	Heliometer—Photographic	Screw-value Correction	Residual
	"	"	"	"	"
Plejone	1402.31	1402.87	+0.56	—0.45	+0.11
Atlas	1390.69	1391.26	+0.57	—0.44	+0.13
26 *s*	1494.33	1494.94	+0.61	—0.47	+0.14
Merope	1106.36	1106.72	+0.36	—0.35	+0.01
Electra	2142.96	2143.43	+0.47	—0.68	—0.21
Celaeno	2298.00	2298.75	+0.75	—0.73	+0.02
Maja	1656.45	1656.90	+0.45	—0.53	—0.08
Taygeta	2276.95	2277.44	+0.49	—0.72	—0.23
Asterope	2070.36	2071.08	+0.72	—0.66	+0.06
22 *l*	1923.73	1924.40	+0.67	—0.61	+0.06

II. Distances of Fainter Stars from Alcyone.

Star	Photographic Distance	Heliometer Distance	Heliometer—Photographic	Screw-value Correction	Residual
	″	″	″	″	″
Anon. 27	979.62	979.63	+0.01	—0.39	—0.38
" 29	1201.79	1202.16	+0.37	—0.48	—0.11
" 31	1806.93	1807.72	+0.79	—0.72	+0.07
" 32	1832.63	1833.33	+0.70	—0.73	—0.03
" 37	1679.25	1679.97	+0.72	—0.67	+0.05
" 33	2199.63	2200.67	+1.04	—0.88	+0.16
" 38	2239.99	2241.01	+1.02	—0.89	+0.13
" 30	1616.24	1616.87	+0.63	—0.64	—0.01
" 34	2323.94	2324.57	+0.66	—0.92	—0.26
" 23	1535.81	1536.78	+0.97	—0.61	+0.36
" 22	688.14	688.64	+0.50	—0.27	+0.23
" 19	1091.20	1091.81	+0.61	—0.43	+0.18
" 17	1372.69	1373.61	+0.92	—0.55	+0.37
" 7	1354.86	1355.45	+0.59	—0.54	+0.05
" 1	1701.50	1702.19	+0.69	—0.68	+0.01
" 9	1044.70	1045.20	+0.50	—0.42	+0.08
24 *p*	117.07	116.81	—0.26	—0.05	—0.31
Anon. 4	1732.93	1733.52	+0.59	—0.69	—0.10
" 10	1002.50	1002.97	+0.47	—0.40	+0.07
" 18	180.55	180.35	—0.20	—0.07	—0.27
" 12	1547.55	1548.22	+0.67	—0.62	+0.05
" 20	1740.48	1741.26	+0.78	—0.69	+0.09
" 21	1986.77	1987.27	+0.50	—0.79	—0.29
" 24	659.46	659.62	+0.16	—0.26	—0.10

III. Position-Angles of Brighter Stars from Alcyone.

Star	Photographic Posit.-Angle	Heliometer Posit.-Angle	Heliometer—Photographic	Index Zero Correction	Residual
	° ′ ″	° ′ ″	″	″	″ ″
Plejone	84 46 42	84 45 17	— 85	+74	— 11 = 0.08
Atlas	97 7 30	97 6 15	— 75	"	— 1 = 0.01
26 *s*	126 1 5	126 0 3	— 62	"	+ 12 = 0.09
Merope	238 46 2	238 45 37	— 25	"	+ 49 = 0.26
Electra	270 14 24	270 12 42	—102	"	— 28 = 0.29
Celaeno	286 13 29	286 12 4	— 85	"	— 11 = 0.12
Maja	304 14 0	304 12 46	— 74	"	0 0.00
Taygeta	304 21 52	304 20 17	— 95	"	— 21 = 0.23
Asterope	320 48 34	320 47 21	— 73	"	+ 1 = 0.01
22 *l*	321 42 0	321 40 59	— 61	"	+ 13 = 0.12

IV. Position-Angles of Fainter Stars from Alcyone.

Star	Photographic Posit.-Angle	Heliometer Posit.-Angle	Heliometer—Photographic	Index Zero Correction.	Residual
	° ′ ″	° ′ ″	″	″	″ ″
Anon. 27	37 49 19	37 49 16	— 3	+51	+ 48 = 0.23
" 29	43 23 51	43 23 59	+ 8	"	+ 59 = 0.34
" 31	54 1 23	54 0 20	— 63	"	— 12 = 0.11
" 32	56 38 20	56 37 5	— 75	"	— 24 = 0.21
" 37	65 55 38	65 54 52	— 46	"	+ 5 = 0.05
" 33	71 38 44	71 37 41	— 63	"	— 12 = 0.10
" 38	113 45 54	113 44 46	— 68	"	— 17 = 0.18
" 30	118 30 30	118 29 14	— 46	"	+ 5 = 0.04
" 34	126 56 58	126 55 53	— 65	"	— 14 = 0.16
" 23	180 35 13	180 35 4	— 9	"	+ 42 = 0.31
" 22	184 44 15	184 44 29	+ 14	"	+ 65 = 0.22
" 19	185 45 41	185 45 29	— 12	"	+ 39 = 0.21
" 17	185 58 2	185 58 1	— 1	"	+ 50 = 0.33

Star	Photographic Posit.-Angle	Heliometer Posit.-Angle	Heliometer—Photographic	Index Zero Correction	Residual
	° ′ ″	° ′ ″	″	″	″ ″
Anon. 7	259 18 19	259 17 31	— 48	+51	+ 3 = 0.02
" 1	260 56 22	260 55 28	— 54	"	— 3 = 0.03
" 9	286 22 42	286 23 31	+ 49	"	+100 = 0.51
24 *p*	289 28 37	289 22 54	—343	"	—292 = 0.17
Anon. 4	298 1 39	298 1 10	— 29	"	+ 22 = 0.19
" 10	301 58 13	301 57 14	— 59	"	— 8 = 0.04
" 18	312 0 44	311 58 38	—126	"	— 75 = 0.07
" 12	344 14 53	344 14 26	— 27	"	+ 21 = 0.18
" 20	357 10 40	357 9 42	— 58	"	— 7 = 0.06
" 21	358 30 18	358 29 42	— 36	"	+ 15 = 0.14
" 24	359 53 52	359 52 48	— 64	"	— 13 = 0.04

The values in the fourth column of the preceding tables are the direct differences between Dr. Gould's figures and the Heliometer results, and on inspection it will be seen that they show throughout a considerable systematic discrepancy in both coordinates between the two measurements. This is doubtless due to the difficulty of determining the reduction constants for the photographs, and as Dr. Gould himself has surmised, the screw-value needs a positive correction, and the zero of position-angle a similar one. I have determined these for the four groups, as follows:

Screw-value correction:

+0″.318 per 1000″ for the brighter stars,
+0 .398 " " " " fainter stars:

Position-angle zero correction:

+74″ for the brighter stars,
+51 " " fainter stars:

and in the last column are given the residuals after these corrections have been applied, those for the position-angles being also expressed as the displacements on the great circle. The highly satisfactory character of these values will be at once apparent: of the 68 values 47 are less than 0″.20, 60 less than 0″.30, and only one exceeds 0″.38, being that for star 9 in position-angle, and amounting to barely half a second. Furthermore, I have not been able to detect any systematic character among them such as would depend on the distance or direction from the center of the field, and about the only manifestation of large constant error is one which seems to affect the group of four neighboring stars, Nos. 23, 22, 19 and 17, and which amounts to about a quarter of a second in both coordinates. Treating all these residuals as casual errors, we find for the probable value of one of them,

For the distances of the brighter stars: ±0″.086,
" " position-angles " " ±0 .106,
For the distances of the fainter stars: ±0 .131,
" " position-angles " " ±0 .137.

To get an estimate of the probable error of the photographic determination we must subtract from these the probable uncertainty of the Heliometer measurement. From the data on page 98 of my *Pleiades* paper I find, neglecting the probable errors of the Heliometer screw-values, which do not enter into this deduction, for the probable error of a Heliometer coordinate for the epoch 1867,

For the brighter stars: ±0″.056,
" " fainter " ±0 .086,

and hence in the mean for the distances and position-angles, which do not appear to be of very unequal accuracy, we deduce the probable error of a coordinate from the photographic measurement,

For the brighter stars: ±0″.079,
" " fainter " ±0 .101.

When it is remembered that these particular photographs do not lay claim to the highest possible accuracy — Dr. Gould himself begs that it "be borne in mind that the present discussion is more for the sake of illustrating the capabilities of the photographic method, even under many disadvantages, than for a definite determination of the best results attainable for the *Pleiades*" — the smallness of these probable errors must be convincing proof that in Photography we have really a means of investigation for micrometric work at least on a par with any existing methods as regards exactitude, and doubtless far surpassing them in ease of measurement and output of work.

I am glad to be able to add a small confirmation of this conclusion from personal experience. During a recent visit to California I had the great pleasure of enjoying for over a month the hospitalities of the Lick Observatory, and of its able director, Prof. Holden, by whose kindness and that of Messrs. Burnham and Barnard, some photographs of the *Pleiades* were taken for me with the great 36-inch telescope. Of these I measured partially 3 plates with the measuring engine of the Observatory, during my stay there, and compared the results with the Yale Heliometer places. The bright stars were much overexposed, and gave a somewhat larger probable error, but the fainter stars, below seventh magnitude, agreed with the Heliometer results almost within the probable errors of these latter, the average deviation being, if my memory serves me rightly, about 0″.11. And these plates were all taken within a few minutes, and the day-time measurements were effected in a fraction of the time it would have taken to make them with the Heliometer.

New Haven, May, 1889.

ON THE COMPARISONS OF THE PHOTOGRAPHIC, WITH THE INSTRUMENTAL, DETERMINATIONS OF STAR-PLACES,

By B. A. Gould.

The foregoing communication of Dr. Elkin and that of Mr. Chase, on p. 167 of Vol. VIII, have peculiar interest, for many reasons; one of which is the full corroboration which they afford of the convictions, strongly expressed by Mr. Rutherfurd and myself, nearly a quarter of a century ago, as to the capabilities of the photographic method of observation.

The history of these researches has been told[1] on various occasions; and it is scarcely worth while to repeat it at any length, although a few words here may not be amiss.

In 1865, Mr. Rutherfurd had devised and constructed his 11½-inch photographic object-glass, and had thus obtained sharply defined impressions of various clusters of stars, notably of the *Pleiades* and the *Praesepe*. He had furthermore constructed a micrometer for measuring the stellar images, and with this had measured their respective distances from a central star, in terms of the micrometer-screw, and their position-angles from the trail left by this star, in passing off the field.

The results of these measurements he kindly placed in my hands, and they afforded the data for the memoirs first printed during the last year. The little memoir on the *Pleiades* was presented to the National Academy of Sciences, 1866 Aug. 11, and an account of it was sent to the *Astron. Nachrichten*, where it will be found in no. 1620 (vol. LXVIII, p. 181). The expedition for determining the transatlantic longitude interrupted these researches; and other circumstances, well known to many, prevented their prosecution for some time, as well as immediate publication of the memoir; and this has remained unaltered, since the date mentioned, excepting that the numerical results of some additional measurements, by Mr. Rutherfurd, were incorporated in the tables. After this slight modification it was handed in again for printing, at the same time with the presentation of the paper on the *Praesepe*, 1870 April 11. When I left home for South America in May 1870, it was under the impression that the two memoirs would be promptly published, together.

Returning home, fifteen years later, I found the manuscripts exactly as I had left them; but in the mean time the photographic method had at last come into favor with astronomers, especially since the introduction of the gelatine-process, which since 1878 has permitted a vast increase in the sensitiveness of the plates. Under the changed circumstances I was at first reluctant to publish the investigations of twenty years previous, without additions and emendations; yet it subsequently appeared best to print these early results in their original form, without the slightest change. Although quite inadequate to the just demands of the present day, their shortcomings in many respects may be offset by their historical character.

These measurements and reductions offer, I believe, the first example of the application of the photographic method to exact numerical determinations in astronomy. Unquestionably they are affected by many sources of error, incident to the first employment of a new method. Indeed, the fact was early recognized by Mr. Rutherfurd, that notwithstanding his care (at first supposed to have been successful) the micrometer-screw had very soon become worn, under the manipulation of inexperienced assistants, and that small changes in the index-errors had occurred between the successive and reasonably frequent determination of these.

The evident distrust of the method by astronomers generally, especially by European ones, led to renewed endeavors to demonstrate its value at the Argentine Observatory in Cordoba; but the history of those efforts, and of the final attainment of photographs of all important southern clusters, need not be repeated here.

The chief technical difficulties were found in maintaining absolute uniformity in the motion of the telescope during the long exposures required by the old process (inasmuch as any elongation of the star-images seriously impairs the precision of the measurements), and in preventing the plates from drying before a sufficiently long exposure had been secured The new dry-plate processes escape both these difficulties; but it remains to be seen to what extent the gelatine-film is exempt from the danger of subsequent distortion, from which the albuminized collodion is known to be free, so long as it adheres fully to the glass plate.

A very large number of stellar photographs were taken at Cordoba in the years from 1872 to 1883; and the measurement of these has been slowly progressing since my return, by the aid of a small appropriation assigned for the purpose by the Argentine Government. Many of the plates have already been fully measured; and among them are some of the *Pleiades* and of the *Praesepe*. The computation of these is well advanced, although not yet completed; and it is my hope to finish this part of the undertaking before long. A comparison of the results will then afford a better test of the method than does that of the earlier ones, recorded in the memoirs lately published.

The atmosphere of Cordoba permitted impressions of stars considerably fainter than those photographed in New York.

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[1] See *American Journal of Science*, since 1864.

"*Address on receiving Premiums awarded at the Centennial Exhibition in Philadelphia*," Cordoba, 1877.

"*On Photographic Determinations of Stellar Positions*," Proc. Amer. Assoc. Adv. Science, XXXV, 74.

etc., etc.

And after a visit to the North, in 1880, had enabled me to obtain a supply of the newly introduced dry plates, stars were habitually photographed at Cordoba which I believe to be as faint as 12^{M}, or even fainter; these being, of course, very white ones. A difference in color, so slight as to be practically inappreciable by the eye, is often sufficient to cause a difference in the photographic images, corresponding to several units of magnitude. This, while it renders the photographs practically useless for photometry, may yet hereafter, by a judicious employment of different chemicals in preparing the plates, be made a means of delicate discrimination for the character of the light of faint stars which have not been examined with the spectroscope.

So much it may be well to say by way of comment upon the results of comparison with instrumental determinations, as given by Dr. Elkin and Mr. Chase. Considering the circumstances, it seems to me that the photographic determinations have borne the test quite as well as could have reasonably been expected in this first essay of the method.

Through the courtesy of Dr. Schur, who has had the goodness to send me some of his own measures of the *Praesepe*, it has been made manifest that the discordance in declination between no. 12 of my list and no. 68 of Prof. Hall's (*A. J.* no. 189) is due to an erroneous record of the photograph-measurement; Hall's value being confirmed by Schur's.

ELEMENTS AND EPHEMERIS OF COMET *b* 1889.

By W. W. CAMPBELL.

The faintness of this comet makes it desirable to have an accurate ephemeris for its morning appearance in July. While it was observed it moved through an apparent arc of less than five degrees, and hence the published elements computed from three observations differ considerably. For these reasons I have corrected my orbit (See *Astr. Jour.* 193) by utilizing all published observations, fifty-seven in number. The observations were compared with an ephemeris based upon the original orbit; the most probable residuals (Obs.–Comp.) were computed for four dates from equations of condition; and the corresponding normal places were formed, with the results as given below.

Gr. M.T.	α	δ	Residuals $\Delta\alpha\cos\delta$	Residuals $\Delta\delta$	No. Obs.	Wt
1889	h m s	° ′ ″	″	″		
Apr. 2.5	5 19 21.01	+16 3 4.2	—0.41	—0.40	14	1
10.5	5 14 0.77	15 46 26.1	+4.59	+0.37	17	1
18.5	5 10 23.93	15 31 2.7	+1.74	+2.60	14	1
26.5	5 8 8.14	+15 16 17.4	+4.51	—0.80	12	½

$vv = 52.31.$

On the supposition that the orbit is a parabola, the usual equations of condition were formed, and solved by the method of least squares, with the following results:

Corrections to the Elements.

$$\Delta T = -0^{d}.000081$$
$$\Delta\omega = -16''.3$$
$$\Delta\Omega = -\ 2\ .9$$
$$\Delta i = +\ 6\ .0$$
$$\Delta\log q = +0.000092$$

Corrected Elements.

$$T = \text{Gr. M.T. 1889 June } 7^{d}.654619$$

$$\left.\begin{aligned}\omega &= 231^{\circ}\ 55'\ 38''.1\\ \Omega &= 310\ \ 51\ \ 11\ .0\\ i &= 163\ \ 53\ \ 25\ .2\end{aligned}\right\}\text{Ecliptic and Mean Equinox 1889.0}$$

$$\log q = 0.354158$$

Equatorial Coordinates.

$$x = [9.990220]\, r\sin(v + 12^{\circ}\ 55'\ 37''.9)$$
$$y = [9.989640]\, r\sin(v + 100\ \ 12\ \ 28\ .1)$$
$$z = [9.478627]\, r\sin(v + 145\ \ 45\ \ 45\ .6)$$

Residuals for Normal Places (Obs.–Comp.).

	$\Delta\alpha\cos\delta$	$\Delta\delta$
	″	″
April 2.5	—0.3	0.0
10.5	+2.5	0.0
18.5	—1.5	+1.5
26.5	+0.1	—2.2

$vv = 1569 \quad v = +0''.1$

Ephemeris for Greenwich Mean Time.

1889	α	δ	$\log r$	$\log\Delta$	Br.
	h m s	° ′			
July 5.5	5 9 16	+12 11.8	0.3587	0.4948	0.88
9.5	5 9 6	11 53.4	0.3600	0.4892	0.90
13.5	5 8 46	11 33.5	0.3515	0.4830	0.92
17.5	5 8 14	11 11.9	0.3631	0.4760	0.94
21.5	5 7 30	10 48.5	0.3648	0.4682	0.97
25.5	5 6 31	10 23.2	0.3668	0.4598	1.00
29.5	5 5 15	9 55.7	0.3688	0.4506	1.03
Aug. 2.5	5 3 39	9 25.8	0.3710	0.4407	1.07
6.5	5 1 41	8 53.2	0.3731	0.4300	1.11
Sept. 5.5	4 29 51	+ 2 54.7	0.3946	0.3319	1.59
Oct. 5.5	3 9 23	— 7 20.5	0.4208	0.2483	2.07
Nov. 5.5	1 15 17	—15 58.3	0.4507	0.2973	1.44

[The brightness at the date of discovery is taken as the unit.]

Ann Arbor, 1889 *June* 8.

EPHEMERIS OF VARIABLES OF THE *ALGOL*-TYPE.

Approximate Greenwich M.T., 1889.

For remarks and comparison-stars see Vol. VII, p. 187 foll. Also, it should be noted that the times for *Y Cygni* are extremely uncertain, probably by several hours; see Vol. VIII, p. 130. Observations in the United States during 1889 have failed to recover the lost minimum epoch, which therefore probably occurs during daylight here, or when the star is below the horizon. An urgent appeal is made to observers in Europe, where observations for its reestablishment may prove to be practicable.

	July		July		July		August		August
	d h		d h		d h		d h		d h
U Ophiuchi	11 17	*Y* Cygni	19 18	Algol	29 17	*U* Ophiuchi	6 17	*U* Ophiuchi	16 18
U Cephei	11 21	*Y* Cygni	21 6	*Y* Cygni	30 6	*Y* Cygni	6 18	*Y* Cygni	17 6
Y Cygni	12 6	*U* Ophiuchi	21 18	δ Librae	31 15	*U* Ophiuchi	7 13	*U* Ophiuchi	17 14
Algol	12 12	*U* Cephei	21 21	*Y* Cygni	31 18	δ Librae	7 14	*U* Ophiuchi	18 10
U Ophiuchi	12 13	*U* Ophiuchi	22 11	*U* Ophiuchi	31 20	*Y* Cygni	8 6	*Y* Cygni	18 18
U Ophiuchi	13 9	*Y* Cygni	22 18	*U* Cephei	31 20	*U* Ophiuchi	8 9	Algol	18 19
Y Cygni	13 18	*U* Ophiuchi	23 11			*U* Coronae	9 10	*Y* Cygni	20 6
U Cephei	14 9	*Y* Cygni	24 6		August	*Y* Cygni	9 10	*U* Cephei	20 18
Y Cygni	15 6	δ Librae	24 15	Algol	1 14	*U* Cephei	10 19	δ Librae	21 13
U Ophiuchi	16 17	*Y* Cygni	25 18	*U* Ophiuchi	1 16	*Y* Cygni	11 6	Algol	21 15
Y Cygni	16 18	*U* Coronae	26 15	*Y* Cygni	2 6	*U* Ophiuchi	11 17	*Y* Cygni	21 18
U Cephei	16 21	*U* Ophiuchi	26 19	*U* Ophiuchi	2 12	*U* Ophiuchi	12 13	*U* Ophiuchi	21 19
U Ophiuchi	17 13	*U* Cephei	26 20	*U* Coronae	2 12	*Y* Cygni	12 18	*U* Ophiuchi	22 15
δ Librae	17 15	Algol	26 20	*Y* Cygni	3 18	*U* Ophiuchi	13 10	*Y* Cygni	23 6
Y Cygni	18 6	*Y* Cygni	27 6	Algol	4 10	*Y* Cygni	14 6	*U* Ophiuchi	23 11
U Ophiuchi	18 10	*U* Ophiuchi	27 15	*Y* Cygni	5 6	δ Librae	14 14	Algol	24 12
U Cephei	19 9	*U* Ophiuchi	28 11	*U* Cephei	5 19	*Y* Cygni	15 18	*Y* Cygni	24 18
U Coronae	19 17	*Y* Cygni	28 18	*U* Ophiuchi	5 21	*U* Cephei	15 19	*U* Cephei	25 18

RING-MICROMETER OBSERVATIONS OF COMET *c* 1888 (*BROOKS. August 7*),

MADE WITH THE 12¼-INCH EQUATORIAL OF THE DETROIT OBSERVATORY,

By W. W. CAMPBELL.

1888 Greenwich M.T.		*	No. Comp	☄ — *		☄'s apparent		log $p\Delta$	
				$\Delta\alpha$	$\Delta\delta$	α	δ	for α	for δ
d	h m s			m s	′ ″	h m s	° ′ ″		
Aug. 23	14 35 45	1	14	−0 17.96	–	12 12 13.	–	9.753	–
24	14 6 4	2	14	+1 10.47	−2 55.1	12 19 32.19	+41 17 35.3	9.762	0.695
	14 47 36	2	12	+1 23.08	−3 47.6	12 19 44.80	+41 16 42.8	9.745	0.757
25	13 58 56	3	9	−0 47.13	+2 30.7	12 26 51.59	+40 16 48.9	9.761	0.663
	14 27 33	3	12	−0 38.65	–	12 27 0.07	–	9.756	–
27	13 54 53	4	7	+0 33.13	–	12 41 13.36	–	9.754	–
	14 14 5	4	11	+0 38.81	−3 23.8	12 41 19.07	+39 40 31.4	9.752	0.700
28	13 58 39	5	8	+1 33.87	−4 17.3	12 48 17.03	+39 5 11.1	9.750	0.673
	14 36 59	6	10	−1 5.96	+3 47.8	12 48 28.15	+39 4 0.1	9.742	0.732
29	14 20 53	7	9	+1 10.18	–	12 55 17.27	–	9.746	–
30	13 50 19	8	14 , 7	+0 43.71	−1 51.2	13 1 54.98	+37 49 38.6	9.743	0.657
	14 27 36	9	10	−1 24.00	–	13 2 5 13	–	9.739	–
Sept. 1	13 39 11	10	12	+1 43.68	−3 19.8	13 15 0.91	+36 29 28.2	9.733	0.641
	14 16 8	11	9 , 8	−2 24.15	−2 31.5	13 15 10.67	+36 28 19.1	9.734	0.697
3	13 39 36	12	10	+2 11.89	−0 9.3	13 27 35.85	+35 4 20.2	9.724	0.642
	14 15 50	13	7	+2 55.21	−3 1.0	13 27 46.53	+35 3 16.9	9.727	0.697
4	13 38 31	14	12 , 7	+1 7.03	+1 41.0	13 33 41.78	+34 20 21.5	9.720	0.641
	14 23 11	15	8	+0 51.15	–	13 33 53.01	–	9.723	–
5	13 40 19	16	14 , 11	+0 53.49	+1 2.1	13 39 39.78	+33 35 50.4	9.716	0.646
6	13 43 19	17	12	+0 28.42	−4 35.4	13 45 29.15	+32 50 18.4	9.712	0.653
8	13 45 24	18	10	+0 40.93	+4 5.7	13 56 43.99	+31 17 55.3	9.705	0.661
	14 5 12	18	10 , 8	+0 45.60	+3 20.9	13 56 48.66	+31 17 10.5	9.708	0.688
	14 27 36	18	10	+0 50.69	+2 37.8	13 56 53.75	+31 16 27.4	9.708	0.717
10	13 35 34	19	12	+2 5.72	+3 9.9	14 6 24.62	+29 44 28.3	9.694	0.656
13	13 36 24	20	12 , 8	+1 55.64	−2 35.7	14 22 31.47	+27 22 43.3	9.683	0.667
24	12 59 43	21	6	+3 22.10	−3 55.5	15 9 31.64	+18 58 6.0	9.632	0.682
Oct. 4	13 40 44	22	5	+3 7.16	–	15 43 44.97	–	9.644	–
8	13 7 20	23	11	+0 46.98	+3 35.9	15 55 38.04	+ 9 45 55.8	9.626	0.740
9	13 4 48	24	8 , 6	+1 15.26	+1 42.0	15 58 29.89	+ 9 11 26.5	9.624	0.742

Mean Places for 1888.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	12 12 31.	—0.58	–	–	DM. +41°2285
2	12 18 22.28	—0.56	+41 20 24.8	+5.6	Weisse's Bessel XII. 346
3	12 27 39.26	—0.54	+40 44 12.3	+5.9	10ᴹ, comp. with W.B. XII. 676–8
4	12 40 40.72	—0.49	+39 43 48.7	+6.5	Bonn VI, +39°2559 [*Nach.* 2871
5	12 46 43.62	—0.46	+39 9 21.8	+6.6	DM. +39°2572, Rome obs., *Astr.*
6	12 49 34.57	—0.46	+39 0 5.6	+6.7	10ᴹ, comp. with Gr. 9-yr. 1196
7	12 54 7.52	—0.43	–	–	Weisse's Bessel XII, 1046
8	13 1 11.67	—0.10	+37 51 22.7	+7.1	" " XIII, 1173
9	13 3 29.53	—0.10	–	–	" " " 11
10	13 13 17.56	—0.33	+36 32 40.5	+7.5	" " " 220
11	13 17 35.15	—0.33	+36 30 43.0	+7.6	" " " 305–6
12	13 25 24.25	—0.29	+35 4 21.9	+7.6	" " " 467–8
13	13 24 51.61	—0.29	+35 6 10.3	+7.6	" " " 456–7
14	13 32 35.	—0.25	+34 18 32.6	+7.9	" " " 618–9
15	13 33 2.11	—0.25	–	–	" " " 628–9
16	13 38 46.51	—0.22	+33 34 40.3	+8.0	" " " 781
17	13 45 0.94	—0.21	+32 54 45.6	+8.2	Harvard obs., *Astr. Jour.* VIII, 135
18	13 56 3.22	—0.16	+31 13 41.2	+8.4	Weisse's Bessel XIII, 1197
19	14 4 19.03	—0.13	+29 41 9.8	+8.6	" " XIV, 37
20	14 20 35.88	—0.05	+27 25 10.2	+8.8	Bonn VI, +27°2375
21	15 6 9.41	+0.13	+19 1 52.7	+8.8	Weisse's Bessel XV, 85 [711
22	15 40 37.56	+0.25	–	–	DM. 12°2894, comp. with W.B. (1)
23	15 54 50.77	+0.29	+ 9 42 11.6	+8.3	DM. 9°3129, comp. with " 902
24	15 57 14.33	+0.30	+ 9 9 36.2	+8.3	Weisse's Bessel (1) XV, 1054

Star Differences.

Stars	No. Comp.	Δα	Δδ
		m s	′ ″
∗ 3—W.B.(2) 676–8	7	—5 50.18	+0 43.7
∗ 6—Gr. 9-yr. 1196	7	—1 13.04	+4 42.2
∗22—W.B.(1) 711	6	+2 9.99	–
∗23—W.B.(1) 902	7	+5 45.53	+3 28.0

[October 4, 8, 9, comet on the limit of vision.]

Ann Arbor, 1889 *June* 12.

OBSERVED MAXIMA AND MINIMA OF VARIABLE STARS, 1888–89,

By PAUL S. YENDELL.

S Sagittae.

By the application of a mean light-curve, the following maxima, in addition to those published in Vol. VIII, page 146, have been deduced from the scattered observations of this star,

1888 June 13.53	1888 Aug. 11.6
22.4	Oct. 8.62
30.17	1889 Feb. 2.71

T Vulpeculae.

A series of 103 observations of this star, extending from June 1, 1888, to June 1, 1889, yields the following maxima to the application of a mean light-curve:

	d	p
1888 June	1.67	3
	9.15	4
1888 June	13.56	3
	18.06	4
1888 June	26.56	2
	30.7	1
July	5.74	3
	9.1	3
	14.73	1
	19.25	2
	23.33	2
	27.8	2
Aug.	9.18	1
	14.9	3
	19.3	3
	23.76	3
	28.36	3
Sept.	5.55	3
	10.5	4
	14.75	2
	25.93	2
	27.8	1
1888 Oct.	11.15	3
	20.58	2
	24.73	3
	29.19	4
Nov.	2.11	2
	6.98	2
	11.34	3
	20.61	3
	30.15	3
Dec.	3.05	3
	21.25	3
1889 Feb.	17.24	2
	21.68	3
	25.22	4
May	26.19	4
	29.78	1
June	3.23	3

T Monocerotis.

Sixty-eight observations of *T Monocerotis*, beginning 1888 Sept. 28, and ending 1889 April 30, give seven maxima and six minima. These have all been deduced by the usual method of single light-curves, with the exception of the maxima of Nov. 13 and March 1 only, which were obtained by the use of a mean curve, formed from all the observations of this and the preceding year, numbering in all 112.

Maxima	p	Minima	p
d		d	
1888 Nov. 13.8	3	1888 Dec. 3.1	4
Dec. 13.0	4	30.	5
1889 Jan. 11.8	5	1889 Jan. 26.8	5
Feb. 4.75	5	Feb. 24.0	5
Mar. 1.92	4	Mar. 24.4	5
30.5	4	Apr. 19.0	4
Apr. 28.8	4		

U Monocerotis.

A good series of observations of this star was obtained, from 1888 Dec. 6 to 1889 April 28, which yielded three maxima and as many minima. The first maximum, Dec. 21.8, was a bright and sharply marked one, and was followed, 1889 Jan. 16.3, by a bright minimum. Between this and the following minimum the star behaved rather oddly, rising to a pretty bright maximum on Jan. 26.2, after which it dropped several steps, and then remained stationary from Feb. 1 to Feb. 18, and from this date rapidly declined to a very faint minimum on March 3.5, when it was nearly equal to the comparison-star *g*. It remained at this point for about a week, rising then steadily and pretty rapidly until it reached a sharply indicated maximum on March 23.3. After this it very nearly repeated its behavior in February, but could not be so closely watched, on account of weather and moonlight. It descended April 22.5 to a bright and not very definitely indicated minimum on April 22.5, after which it was rising pretty rapidly when the last observation, April 28, was made.

Maxima	p	Minima	p
d		d	
1888 Dec. 21.8	1	1889 Jan. 16.3	3
1889 Jan. 26.2	3	Mar. 3.5	5
Mar. 23.3	4	Apr. 22.5	2

I regret that I have not the means at hand of estimating the magnitudes of the star at the several phases; as its behavior during the season has been of an exceedingly interesting character.

R Leonis.

This star was observed 45 times from Jan. 23 to May 19, 1889. A maximum is indicated April 16. The star was pretty bright at the maximum, being two steps >18 *Leonis*, or about sixth magnitude.

S Coronae.

Twenty-five observations of *S Coronae*, from March 23 to May 24, 1889, show a maximum to have been passed April 13.

S Serpentis.

This star was first looked for on the morning of March 13, but was not seen with the $4\frac{1}{4}$-inch refractor; it was found on the evening of March 28, when its light was estimated to equal that of DM. 14°2868, or $8^{\mathrm{M}}.5$, from which brightness it increased steadily until May 5, when its light was 4 steps > DM. 14°2866, equivalent to $7^{\mathrm{M}}.4$. From this point it rapidly declined, and when last observed, on May 18, was 4 steps < DM. 14°2868, 9.0 magnitude.

A projection of the light-curve shows a maximum to have passed on May 4, 1889.

Dorchester, Mass., 1889 *June* 8.

COMET *c* 1889.

A faint comet was discovered June 23, by Barnard, in the position,

1889 June 23.9499 G.M.T. $\alpha = 1^{\mathrm{h}}\ 20^{\mathrm{m}}\ 53^{\mathrm{s}}.4$ $\delta = +38°\ 50'\ 41''$. Daily motion in α, $+4^{\mathrm{m}}\ 24^{\mathrm{s}}$; in δ, 34′ northward.

Prof. Holden telegraphs an orbit computed by Leuschner, from observations of June 23, 24 and 25, as follows:

$T =$ 1889 June 20.15 Greenw. M.T.
$\omega = 59°\ 21'$
$\Omega = 271\ \ \ 4$
$i = 31\ \ \ 15$
$q = 1.1024$

Ephemeris for Greenwich Midnight.

1889	α	δ	Brightness
	h m s	° ′	
June 29	1 47 4	+41 51	0.92
July 3	2 5 48	+43 40	
7	2 24 20	+45 11	
11	2 42 36	+46 27	0.76

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LAPLACE'S SOLUTION OF THE TIDAL EQUATIONS.

By WILLIAM FERREL.

For nearly ten years I have been too much engaged in other duties and lines of research to give much attention to tidal matters, or to follow up closely the profound researches of Professor G. H. Darwin on tidal subjects, and have not until now examined his article on tides contributed to the *Encyclopaedia Britannica.* Very recently Mr. Basset's recent treatise on Hydrodynamics was handed to me by a friend, and in glancing over it, I came to the part which treats of the tides. This purported to be mostly an abstract from Professor Darwin's article in the *Encyclopaedia* in which the part which treats of semi-diurnal tides is said to be substantially contained in a paper by Sir W. Thomson, in defence of Laplace's solution of the tidal equations, and in opposition to Airy's solution. In both Darwin's article and Mr. Basset's book the following statement with reference to Laplace's process is found: "This process was followed by Laplace without explanation. It was attacked by Airy in his *Tides and Waves* (in *Encyc. Metrop.*), and by Ferrel in his *Tidal Researches* (U.S. Coast Survey, 1873), but was justified by Sir W. Thomson in the *Phil. Mag.*, 1875, p. 230."

As this matter has now passed into the *Encyclopaedia*, and into at least one text-book in connection with my name, it becomes not only proper, but even necessary, to take up this subject again, lest continued silence should be interpreted to mean a confession of error, and a giving up of the controversy. In my recent thorough review of the matter I have gained additional light on the subject; and for this reason, also, I am induced to take up the matter again in order to make some points more clear than I have heretofore.

Airy's reply to Sir W. Thomson's paper, referred to above, is found in the same volume of the *Phil. Mag.*, and a reply by myself in the next volume, p. 282, 1876. It is proposed here to consider first Sir W. Thomson's justification of Laplace's solution, and in all which follows I will adopt Darwin's notation, and make his article a basis, as it is now perhaps more accessible to most readers than any other on this subject.

With regard to the general equations of motion, Darwin (17), and the equation of continuity (18), and the final equation (24) deduced from them, and equation (33) deduced from this for the special case of semi-diurnal tides, all are agreed; and the whole controversy is simply with regard to the solution of this latter equation, and the interpretation of the result.

This equation is satisfied with an expression of u of the form of Darwin (34). Substituting this and its first and second derivatives in (33), and equating the coefficients of like powers of r to 0, we get

$$\begin{aligned} K_2 &= E \\ K_4 &= K_4 \qquad\qquad (1) \\ K_6 &= \tfrac{5}{8}K_4 - \tfrac{1}{16}\beta E \\ K_8 &= (\tfrac{7}{16} - \tfrac{1}{40}B)\, K_4 - \tfrac{7}{160}\beta E \end{aligned}$$

and after K_4 only the relation given by Laplace,

$$2i(2i+6)K_{2i+4} - 2i(2i+3)K_{2i+2} + \beta K_{2i} = 0 \qquad (2)$$

This is substantially the same as the more simple and convenient form given in *Tidal Researches.* The value of i above may be any integral number commencing with unity. From this the value of any coefficient K_{2i} may be obtained from the two preceding ones after K_4, where alone this relation between the coefficients is found. In this case, as usual, the general law is not found at first, and it is well known that in many such cases the general law is not reached until after the fourth or fifth term. Now it is evident that the equation is satisfied with any value of K_4 whatever, and consequently K_4 is indeterminate, according to the universal interpretation of an identical equation thus obtained. Darwin admits that it is apparently so; so that whatever value we give to K_4 in (1) above we get values of K_{2i} generally, which in Darwin (34) gives a value of u which satisfies the tidal equations, and is a true solution of the problem. But Laplace and Thomson extend the relation of (2) above, found by equating the coefficients of like powers of r *after* K_4 only, back to K_2 and K_4, and by means of the continued fraction obtain a determinate value of K_4 such as is not found directly by equating the coefficients of r^4. With regard to this process Airy justly says, "I scarcely need remark that I look upon Laplace's process as a mere sport with symbols, and upon LAPLACE's conclusion as a grievous error."

THOMSON not only extends the relation of (2) above back where it does not belong, but after showing that the limiting ratio between K_{2i+2} and K_{2i}, deduced from it when i becomes infinitely great, is unity, he says it must be so changed as to make the ratio converge to zero instead of unity, and that LAPLACE determined his K_4 upon this principle. That is, LAPLACE established a certain general relation between the coefficients, expressed by (2) above, which makes the final ratio unity, and then determined his K_4 in violation of this relation and upon the principle that this ratio must finally converge to zero. This seems to me to be reasoning against rather than in favor of LAPLACE's value of K_4.

The reason which THOMSON gives why the vanishing ratio must be zero, and not unity, is that otherwise the expression $\frac{du}{d\theta}$ obtained from DARWIN (34) does not become zero at the equator, and consequently the meridional displacement of the water at the equator does not vanish, as symmetry requires that it should. For it is seen from DARWIN (23), that unless $\frac{du}{d\theta} = 0$, the coefficient x of this displacement does not vanish at the equator where $\cos\theta = 0$. But it is readily seen from a mere inspection of DARWIN (34) that $\frac{du}{d\theta}$ does become 0 at the equator, since each term has the factor $\cos\theta$ which is there equal zero, and so whatever the relation between the coefficients, and whether the series is convergent, non-convergent, or divergent, it makes the meridional displacement zero at the equator. The slow final convergency of the series at the equator may be unfortunate practically, but no argument can be deduced from it, as THOMSON endeavors to do, in favor of LAPLACE's K_4. A large value of K_4 makes the series more convergent at first, but still the final ratio between successive terms has to come to unity at the equator, where $r = 1$, in accordance with LAPLACE's law, given in (2) above.

Again, THOMSON remarks, that $K_4 \div K_2$ cannot but be equal to the value of the continued fraction, and that K_4, therefore, must have the value obtained by LAPLACE. But this is a mere begging of the question, for it assumes that the relation of (2) above must be extended back to K_4 and K_2, which is the main point controverted. What is wanted here, is an explanation of why it is necessary to resort to the continued fraction to determine an indeterminate quantity.

With the additional light which I now have from my recent study of the subject, there is one thing in my reply to THOMSON, referred to above, which I now wish to recall, and that is the concession which I made to a point taken by him in his paper, stated there, as here, in italics: "*Whatever other motion* (than that given by LAPLACE's solution) *the sea could have in virtue of any initial disturbance cannot, except for certain critical depths, have the same period as the tide-generating forces.*" This point, too hastily conceded in my reply, is not true. In tides on an ocean of equal depth covering the whole earth with a rotation on its axis, there is no critical depth only, as in canals, at which the free tide-wave may have the same period as that of the tide-generating force, but *free oscillations may exist, for any given depth of ocean, having any period whatever.*

This proposition admits of conclusive demonstration. It simply becomes a special case of the general problem in which we must put in DARWIN (17) $\mathfrak{e} = 0$, since this becomes 0 when $\mathfrak{e} = Er = 0$, and consequently when the tide-generating forces vanish. And this special case needs no special solution, but is contained in the general solution, and the successive values of K_{2i} in DARWIN (34) in this case are obtained from (1) above by putting $E = 0$. We thus get K_4 any assumed value. $K_6 = \frac{5}{8}K_4$, $K_8 = (\frac{7}{16} - \frac{1}{40}\beta)K_4$, and so on. All these values depend upon the assumed K_4, and are independent of any tidal forces, but simply upon initial motions which the water must have which satisfy the condition of continuity, and the conditions of DARWIN (17) in the case in which $\mathfrak{e} = 0$. The value of n in the equations, and in the expressions of (1), since $\beta = \frac{4a^2n^2}{gl}$ determine the periods of oscillation, by DARWIN (20). And there is nothing in the equations which limits them to any critical depth or given period, since l and n in the expression of β may have any values whatever. In this case we have from the equation $h = e + u$, $h = u$, and consequently with this value of u we get the value of $\mathfrak{h}$ in (17).

But even if it were not admitted that the equations apply in this case, then let it be supposed that the equations are solved for some given value of $\mathfrak{e}$ in DARWIN (17), and that the values of $\frac{d\eta}{dt}$ and $\frac{d\xi}{dt}$ are those which depend entirely upon the tidal forces. Now let us suppose that these values are doubled over every part of the earth by some sudden impulse. These doubled velocities would of course satisfy the equation of continuity, and they would give double values to the first terms of (23), and the whole of the left-hand members of the equations would be doubled. In this case, $\mathfrak{h} - \mathfrak{e}$ would be doubled, but $\mathfrak{e}$ remaining the same $\mathfrak{h}$ would have a greater value than before with the same period of oscillation, and this excess would depend, not upon $\mathfrak{e}$ which remains the same, but upon the increased initial motions of the water which give rise to deflecting forces arising from the earth's rotation, and expressed by the terms in the equations containing n as a factor. This increased tide, therefore, is a free tide independent of the tidal forces, and depending only upon the increased initial motions, but existing in connection with that depending upon the tidal forces, and having the same period.

Another important proposition, for which we shall have use, can also be deduced from the general equations almost from a mere inspection of them. Suppose we have a solution of the equations in any given case, either with tidal forces or in the case in which they vanish. To this solution corresponds certain values of the velocities $\frac{d\eta}{dt}$ and $\frac{d\xi}{dt}$. If now we put in Darwin (17),

$$(3)\qquad n\frac{d\eta}{dt} = c \qquad n\frac{d\xi}{dt} = c'$$

c and c' being constants for any given place on the earth, then we have the velocities of the water inversely as the velocity of the earth's rotation. Whatever the velocities of the water and that of the earth's rotation, provided they fulfil this condition, all the terms of the first members of Darwin (17) have the same values, and hence $\mathfrak{h} - \mathfrak{e}$, that is, we have the same tide, but with a different period. Hence, *if all the velocities are increased in the same ratio as the velocity of rotation is diminished, we have the same height of tide.* But of course these velocities depend mostly upon the initial motions, and not upon the tidal forces, and are simply free tides existing in connection with the real tide, and must rapidly disappear in the case of friction.

In the solution of the equations for diurnal tides, Darwin, in his article for the *Encyclopaedia*, substantially follows Laplace, and arrives at the same remarkable result, that there is no diurnal tide where the depth of the ocean is everywhere the same. This is done without regard to certain criticisms which I made upon that solution more than thirty years ago (*Astr. Journal*, IV. 173), and then again about fifteen years ago (*Tidal Researches*, p. 151), and so it becomes necessary to take up again this part of the subject, and with all due deference to high authority I must here enter a protest against the correctness of this solution.

Laplace, in the solution of the equations in this case, assumes that the value of u, in a sea of uniform depth, is of the form of

$$(4)\qquad e = E\sin\theta\cos\theta$$

that is, of the form of the potential of the tide-generating forces, and he finds that the equations are satisfied with this form, and he gets a definite result which makes the tide vanish. But note that he adds to the conditions expressed by the tidal equations still another one, namely, that the value of u shall have a given form, that of (4) above. In my solution of the equations in this case, it is assumed that the expression of u satisfying the equations, putting r for $\sin\theta$, is of the more general form:

$$(5)\qquad u = A_1 r + A_3 r^3 + \; . \; . \; . \; . \; . \; . \; A_i r^i$$

in which the value of i may be any integral odd number commencing with unity. Substituting this expression of u and that of its first and second derivatives, and also that of e in (4) above developed into the same form, in the tidal equation, and, equating to zero the coefficients of like powers of r, I get

$$(6)\qquad A_1 = A_1 \qquad A_3 = -\tfrac{1}{2}A_1 + \tfrac{3}{8}\frac{n^2}{gl}(A_1+E)$$

and so on, g and l here being supposed to be expressed in terms of the earth's radius, but only after A_i is a common relation, between any coefficient A_i and the three preceding ones established. For this expression and other details of the solution the reader is referred to my solution in the papers above referred to. The result of $A_1 = A_1$ with this more general assumed form of expression shows that the problem in this case, as well as in that of the semi-diurnal tides, is indeterminate, and that there may be as many different values of u which satisfy the conditions of the problem as there can be assumed values of A_1, and the problem is only determinate when the additional condition is imposed upon the problem that u shall have the form of e in (4) above, in which case all the conditions are satisfied with Laplace's result alone. From the very form which the development of e in (4) assumes, it is evident that the expression of u must be of the form of (5), but it does not follow that the relation between the coefficients of A_i shall be the same as in the development of e in (4) as required by Laplace's assumption. Now, if this solution and Laplace's are both correct, and the latter is simply a special case of the former more general one, then some value of A_1 should be found which gives Laplace's result. Such a value is $A_1 = -E$. With this value (5) above by means of (6) gives

$$\begin{aligned} u &= -\,Er(1-\tfrac{1}{2}r^2-\tfrac{1}{8}r^4-\text{etc.}) \qquad (7)\\ &= -\,E\sin\theta\cos\theta = -e \end{aligned}$$

This value of u in the expression $h = e + u$ gives $h = 0$, which is exactly Laplace's result. But this is simply one of an infinite number of results which satisfy the conditions of the tidal equations, and the single one which also satisfies them in the restricted case in which the form of u is required to have the assumed form of (4) above. But as this result is obtained by giving a value to A_1, it is not a result which depends alone upon the tidal forces, but one in which a tide independent of the forces, and depending upon the deflecting forces arising from the earth's rotation in connection with certain initial motions given to the water, which, as has been shown above, can exist with the other having the same period of oscillation. And this latter in the case of $A_1 = -E$ exactly counteracts the other, and makes the tide vanish. But in the vanishing of the tide the horizontal motions of the water do not vanish, but we get in this case from Darwin (23), as shown by Mr. Basset,

$$x = \frac{E}{m} = \frac{gE}{an^2}$$

$$y\sin\theta = -\frac{E}{m}\cos\theta = -\frac{gE\cos\theta}{an^2}$$

And with these we get from Darwin (20) for the velocities, putting in this case $2f = 1$,

$$\begin{aligned} \frac{d\xi}{dt} &= -\frac{gE}{an}\sin(n+\varsigma+a) \qquad (8)\\ y\sin\theta\frac{d\eta}{dt} &= -\frac{gE\cos\theta}{an}\cos(n+\varsigma+a) \end{aligned}$$

It is admitted above that Laplace's result is one of an infinite number which satisfy the conditions in the case of no friction, but it is one which does not depend alone upon the tidal forces, but also upon certain initial motions which the water may be conceived to have. But this is not what LAPLACE claims for it, but he claims that it is a result depending upon the tidal forces alone after friction has destroyed all others depending upon initial motions merely. But now note the result which we get from (8) above, which is obtained upon the hypothesis of a vanishing tide. The expressions of (8) are obtained from equations which must hold for all values of n, however small, and so when n vanishes. As the velocity n of the earth's rotation is diminished the velocities of the water increase, and when n vanishes they become infinite. It should be stated here, however, that when the velocities become very great in comparison with that of the earth's rotation, the equations fail in consequence of certain neglected terms in DARWIN (15) then becoming too large to be neglected, and so instead of becoming infinite the velocities would only become very great. But if the vanishing tide is a true tide depending upon the tidal forces only, then it is evident that as n is diminished the tidal velocities diminish, and when n becomes 0 we have the equilibrium tide in which all motion ceases. But LAPLACE's solution gives no such result and therefore does not give a tide depending upon the tidal forces alone.

The preceding result is entirely clear if we admit that LAPLACE's result depends in part upon a tide arising merely from initial motions and which counteracts and destroys the real tide. For then by (3) above, in order to have the same tide as the velocity of rotation is diminished, or as in this case, to have a vanishing tide for all velocities of rotation, we must have the velocities inversely as n, just as given by (8) above.

But in order to make this matter still clearer to those who are not able to grasp the more complex cases, I will take the following very simple case, which, however, is a special case in the general solution. Suppose the disturbing body, sun or moon, to stand over one of the poles of the earth, we then have instead of, (4),

$$e = E\,(3\cos^2\theta - 1). \tag{9}$$

But in this case $\mathfrak{e}$ and $\mathfrak{h}$ are independent of longitude and become equal to e and h. The general equations of DARWIN (17) in this case are satisfied by assuming that the water has a uniform velocity $\frac{d\eta}{dt}$ around the earth, but no meridional component. Of course such a motion satisfies the equation of continuity. In this case the second of DARWIN (17) disappears, and we get from the first one (10)

$$2n\sin\theta\cos\theta\,\frac{d\eta}{dt} = \frac{g}{a}\,\frac{d}{d\theta}\,(h - e) = \frac{g}{a}\left(\frac{dh}{d\theta} + 3\,E\cos\theta\sin\theta\right)$$

It is seen from this equation that the problem is indeterminate and that we get as many different values of $\frac{dh}{d\theta}$ and consequently of h, as we assume values of $\frac{d\eta}{dt}$ for the different latitudes. But if it is required that h shall have a given form then certain determinate values of $\frac{d\eta}{dt}$ are required at each latitude. For instance, if it is required that dh, and consequently a change of level in different latitudes, shall vanish, we get from (10)

$$\frac{d\eta}{dt} = \frac{3gE}{2\,an} \tag{11}$$

That is, an angular velocity, which is the same for the different latitudes, satisfies this condition. It is readily seen that in this case the force which counteracts the attractive forces of the sun or moon is simply that of the deflecting force of the earth's rotation belonging to the easterly velocity of the water, or, in other words, the increased centrifugal force arising from increasing the angular eastward velocity of rotation $\frac{d\eta}{dt}$ to that of the earth's rotation n. Now it is seen from (11) that this velocity, as in other cases, has to be increased as the velocity of rotation is diminished, and the reason is very obvious from general considerations. Now any one can see that this result, this vanishing of the tide, so to speak, simply arises from an initial eastward velocity of the water, and when this is destroyed by friction we get the equilibrium state depending simply upon the forces.

Washington, D.C., 1889 *May* 22.

A CORRECTION,

BY WILLIAM A. ROGERS.

Professor SAFFORD makes the following statement on page 25 of his *Memoir on the Williams College Catalogue of North Polar Stars:*

"Professor ROGERS's catalogue is said to be 'reduced to the standard of Publication XIV.' I cannot find anywhere a definite statement whether for these stars the reduction is simply made by the help of the fundamental places of Publication XIV, or whether for certain other stars systematic corrections have been applied."

It will be seen, by reference to pages lxxi–lxxiii of the Introduction to Volume XVI of the *Annals of Harvard College Observatory*, that the information sought is plainly given. In order to correct the erroneous impression conveyed by the statement of Professor SAFFORD, it seems worth while to repeat the statement made in the Introduction to Volume XVI. The sentence here printed in italics is not so printed in the original.

The tabular corrections to the places of certain stars, both in right-ascension and declination, are also given to facilitate the comparison of the predicted corrections with the final corrections, which will doubtless be soon determined.

[Quotation from the Introduction to Vol. XVI, *Annals of Harvard College Observatory*.]

The instrumental constants depend upon the positions in the catalogue of 539 stars given in Publication XIV of the *Astronomische Gesellschaft*. In the reduction of the observations, it was found that a few stars persistently gave values of $(\Delta T+m)$, or of R_{eq} differing appreciably from the mean values of these functions, for each date of observation. In every suspected case, the residual between the observed value and the mean value was taken during the entire series from 1871 to 1879. The cases which were noted in this way were then grouped together for the entire interval, and then, for the first time, an examination was made of the recurrence of the same errors for each year. From this provisional list were selected all the stars which appeared to require corrections to the positions of the *Fundamental Catalogue*. A special examination was made of these stars, resulting in the following list of corrections. In the adjacent column, the corresponding corrections obtained from the complete reduction of the observations, are given.

TABLE XVII.

PROVISIONAL AND FINAL CORRECTIONS TO THE PLACES OF CERTAIN STARS IN THE CATALOGUE OF PUBLICATION XIV.

Star	R.A.	δ	Provis. Correct'n	Final Correct'n	Star	R.A.	δ	Provis. Correct'n	Final Correct'n
				In Right-Ascension.					
	h m	° ′	″	″		h m	° ′	″	″
ι *Ceti*	0 13	— 9 31	+0.05	+0.05	φ *Herculis*	16 5	+45 16	+0.07	+0.08
μ *Cassiopeae*	0 42	+57 9	+0.09	+0.09	η *Draconis*	16 22	+61 48	—0.17	—0.16
β *Andromedae*	1 3	+34 57	—0.07	—0.05	Groombridge 2377	16 43	+57 0	—0.13	—0.11
36 *Lyncis*	9 6	+43 44	—0.16	—0.09	ξ *Draconis*	17 51	+56 54	—0.11	—0.12
υ *Ursae Majoris*	9 42	+59 38	—0.04	—0.02	33 *Cygni*	20 10	+56 11	—0.10	—0.10
θ *Draconis*	16 0	+58 51	—0.12	—0.09	λ *Andromedae*	23 31	+45 47	—0.08	—0.06
				In Declination.					
α *Cassiopeae*	0 33	+55 51	+0.5	+0.5	ε *Serpentis*	15 45	+ 4 51	—0.7	—0.5
α *Tauri*	4 29	+16 15	—0.8	—0.2	Groombridge 2296	15 55	+55 6	+0.6	+0.4
λ *Eridani*	5 3	— 8 55	—1.6	—0.9	γ *Herculis*	16 16	+19 27	—0.6	—0.8
α *Orionis*	5 48	+ 7 23	+0.6	+0.2	Groombridge 2377	16 43	+57 0	+0.6	+0.5
ν *Orionis*	6 0	+14 47	—0.5	—0.8	ε *Ursae minoris*	16 59	+82 14	+0.6	—0.1
23 H *Camelopardalis*	6 25	+79 42	+1.5	+1.1	β *Draconis*	17 28	+52 24	+0.5	+0.1
θ *Geminorum*	6 45	+34 7	—0.6	—1.1	γ *Draconis*	17 54	+51 30	+0.4	+0.4
δ *Cancri*	8 38	+18 37	—0.9	—0.9	Groombridge 2655	18 36	+77 27	+0.8	+0.8
σ² *Cancri* med.	8 47	+31 3	+0.7	+0.5	δ *Aquilae*	19 19	+ 2 52	+1.2	+0.6
ζ *Hydrae*	8 49	+ 6 25	+0.5	+0.6	δ *Sagittae*	19 42	+18 14	—1.0	—0.9
83 *Cancri*	9 12	+18 14	—0.6	—0.6	η *Aquilae*	19 46	+ 0 41	—0.6	—0.3
α *Hydrae*	9 21	— 8 7	—0.4	+0.1	ε *Cygni*	20 41	+33 30	—0.8	—0.3
η *Leonis*	10 1	+17 22	—0.7	—0.6	ι *Pegasi*	22 1	+21 44	—0.6	—0.4
γ *Ursae Majoris*	11 47	+54 23	+0.5	+0.2	θ *Pegasi*	22 4	+ 5 35	+1.2	+0.6
η *Virginis*	12 14	+ 0 2	—0.6	—0.5	ο *Andromedae*	22 56	+41 39	—0.5	—0.4
τ *Virginis*	13 55	+ 2 9	+0.9	+0.6	π *Cephei*	23 4	+74 13	—1.4	—1.1
ρ *Bootis*	14 26	+30 55	+0.5	+0.3	ω *Piscium*	23 53	+ 6 10	+0.6	+0.3
α *Serpentis*	15 38	+ 6 49	+0.6	+0.5					

It will be seen from the tabular corrections in declination that the plus and minus signs are nearly equally distributed. Since the corrections are small, they will, even if they are real, have but little effect upon the final value of R_{eq} for any date. *No account, therefore, has been taken of the corrections in declination.*

Under the approval of the Council of the Gesellschaft, all the corrections in right-ascension, given above, have been applied in the final computation of $(\Delta T+m)$. But it is to be observed that, in the determination of the constant n, these stars were omitted from the equations, with the exception of η *Draconis*, to which the correction $-0^s.16$ was applied.

For the years 1883 and 1884, the following corrections in right-ascension were introduced in the determination of n and of $(\Delta T+m)$:

Star	R.A.	Cor. to Fund. Catalog.
	h m	s
Groombridge 29	0 9	+0.15
λ *Cassiopeae*	0 42	+0.09
Groombridge 966	5 23	—0.06
1 H *Draconis*	9 19	+0.21
θ *Draconis*	16 0	—0.09
η *Draconis*	16 22	—0.19
Groombridge 2377	16 43	—0.09
Groombridge 2655	18 36	—0.13
Groombridge 2900	19 29	+0.15
11 H *Cassiopeae*	23 42	+0.03

The following corrections were used in the reductions for 1885, in addition to those given above:

	h m	s
25 *Monocerotis*	7 31	+0.14
27 *Lyncis*	7 59	+0.08
υ Ursae Majoris	11 12	—0.09
β Crateris	11 5	+0.11
69 H *Ursae Majoris*	13 24	—0.08
θ Cephei	20 28	—0.10
α Cygni	20 37	—0.07
61^1 *Cygni*	21 1	+0.15

No corrections in declination were applied for the years 1883, 1884 and 1885, but the following stars were excluded in the determination of R_{eq} for 1885, viz.: *δ Aurigae*, 69 *H Ursae Majoris*, 35 *Draconis* and *β Lyrae*.

Colby University, Waterville, Me., 1889 *June* 7.

ELEMENTS AND EPHEMERIS OF COMET *c* 1889 (*BARNARD*),

W. W. CAMPBELL.

These elements and ephemeris were computed from the three following observations:

	Gr. M.T. 1889	App. α	App. δ
		h m s	° ′ ″
Lick,	June 23.9499	1 20 53.4	+38 50 44
Lick,	30.8775	1 53 33.1	+42 30 9
Ann Arbor,	July 5.8067	2 16 40.71	+44 34 23.4

Elements.

$T =$ 1889 June 20.64221 Gr. M.T.

$$\left.\begin{aligned}\omega &= 60^\circ\ 54'\ 57''.2\\ \Omega &= 271\ \ 25\ \ 11\ .2\\ i &= 31\ \ 21\ \ 23\ .6\end{aligned}\right\}\ \text{Ecliptic and Mean Equinox 1889.0}$$

$\log q = 0.049016$

$$\text{Residuals (O—C)}\ \left\{\begin{aligned}\cos\beta'\Delta\lambda' &= +3''.5\\ \Delta\beta' &= +6''.0\end{aligned}\right.$$

Equatorial Coordinates.

$$\begin{aligned}x &= [9.931479]\ r\sin(v+\ \ 62^\circ\ 34'\ 42''.1)\\ y &= [9.971327]\ r\sin(v+319\ \ 20\ \ 57.2)\\ z &= [9.797917]\ r\sin(v+\ \ 21\ \ 35\ \ 49.3)\end{aligned}$$

Ann Arbor, 1889 *July* 8.

Ephemeris for Greenwich Mean Time.

1889	α	δ	log r	log Δ	Br.
	h m s	° ′			
July 11.5	2 42 42	+46 24.4	0.0679	0.0962	0.75
13.5	2 51 42	46 57.0	0.0716	0.1011	
15.5	3 0 35	47 26.2	0.0754	0.1060	0.68
17.5	3 9 19	47 52.3	0.0795	0.1107	
19.5	3 17 55	48 15.5	0.0837	0.1154	0.63
21.5	3 26 20	48 35.8	0.0882	0.1198	
23.5	3 34 35	48 53.5	0.0929	0.1242	0.58
25.5	3 42 38	49 8.7	0.0977	0.1284	
27.5	3 50 29	49 21.8	0.1027	0.1325	0.54
29.5	3 58 7	49 32.7	0.1078	0.1363	
31.5	4 5 33	49 41.7	0.1130	0.1401	0.50
Aug. 2.5	4 12 45	49 48.9	0.1184	0.1436	
4.5	4 19 44	49 54.4	0.1238	0.1471	0.46
6.5	4 26 29	49 58.3	0.1293	0.1503	
8.5	4 33 0	50 1.0	0.1349	0.1534	0.42
10.5	4 39 17	50 2.3	0.1405	0.1563	
12.5	4 45 20	50 2.6	0.1462	0.1591	0.38
14.5	4 51 9	50 1.9	0.1519	0.1616	
16.5	4 56 43	+50 0.2	0.1577	0.1641	0.36

The Lick observations were communicated by telegraph. The Ann Arbor observation was made in a thick sky, and the nucleus was not visible. It depends upon the star *Paris* 2998.

OBSERVATIONS OF COMET *c* 1889,

MADE AT THE HAVERFORD COLLEGE OBSERVATORY,

By F. P. LEAVENWORTH.

1889 Haverford M.T.	∗	No. Comp.	☄ — ∗		☄'s apparent		log pΔ	
			Δα	Δδ	α	δ	for α	for δ
d h m s			m s	′ ″	h m s	° ′ ″		
June 27 13 59 48	1	5	—0 58.06	—0 30.7	1 39 0.01	+40 59 7.5	n9.768	0.527
July 5 13 15 54	2	1	—2 23.0	—3 2				
" " "	3	1	—2 35.7	—1 18				

∗	α	Red. to app. place	δ	Red. to app. place.	Authority
	h m s	s	° ′ ″	″	
1	1 39 57.94	+0.13	+40 59 48.5	—10.3	Weisse's Bessel I, 871

The observations were made with a square-bar micrometer.

The comet was extremely faint on both nights, the nucleus appearing as a star of the thirteenth magnitude.

DISCOVERY AND OBSERVATIONS OF A COMET.

By E. E. BARNARD, Astronomer of the Lick Observatory.

On the morning of June 24, at about 2^h, I discovered a faint comet in *Andromeda* with the 6½-inch equatorial.

The following are the observations so far obtained:

FILAR-MICROMETER OBSERVATIONS OF COMET *c* 1889 (*BARNARD, June 23*).

MADE WITH THE 12-INCH EQUATORIAL.

1889 Mt. Hamilton M.T.	✱	No. Comp.	☄—✱ Δα	☄—✱ Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
d h m s			m s	′ ″	h m s	° ′ ″		
June 23 14 41 21	1	8 , 7	—0 37.73	+3 36.7	1 20 53.11	+38 50 43.6	*n*9.745	0.387
24 13 56 14	2	12 , 6	+0 13.12	—9 20.6	1 25 26.25	+39 21 39.6	*n*9.774	0.510
25 12 59 4	3	24 , 8	—0 18.50	—4 43.9	1 29 58.36	+39 57 11.7	*n*9.787	0.634
26 13 23 57	4	5	–	+5 50.3	–	+40 30 35.5	–	0.594
14 4 0	4	8	—1 56.90	–	1 34 53.93	–	*n*9.779	–
29 12 46 43	5	14 , 9	—0 17.89	+1 9.6	1 48 18.20	+42 1 31.5	*n*9.794	0.661
30 12 57 0	6	12 , 8	+1 6.66	+3 42.6	1 53 33.14	+42 30 8.7	*n*9.798	0.643
July 1 13 38 3	7	14 , 10	—2 2.17	—8 21.1	1 58 23.53	+42 58 8.5	*n*9.805	0.525
2 13 47 28	8	16 , 10	—1 27.07	+4 58.0	2 3 8.32	+43 21 27.2	*n*9.807	0.511

Mean Places for 1889.0 of Comparison-Stars.

✱	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	1 21 31.05	+0.09	+38 47 16.9	—10.0	Weisse's Bessel I, 419–420
2	1 25 12.74	+0.09	+39 34 10.3	—10.1	" " I, 503–508
3	1 30 16.75	+0.11	+40 2 8.7	—10.1	" " I, 625
4	1 36 50.71	+0.12	+40 24 56.1	—10.2	" " I, 805
5	1 49 5.95	+0.14	+42 0 32.1	—10.2	Comp. with Weisse's Bessel I, 1182
6	1 52 26.32	+0.16	+42 26 36.1	—10.0	Weisse's Bessel I, 1184
7	2 0 25.57	+0.13	+43 6 39.7	—10.1	Lal. 3849
8	2 4 35.26	+0.13	+43 19 39.3	—10.1	Weisse's Bessel II, 15

June 23. Comet faint, with no condensation and no tail.
June 24–25. Probably somewhat more condensed.
June 26. Excessively difficult in haze, but observations good.
June 29. ✱5 — W.B. 1182; $\Delta\alpha = -3^m 1^s.14$, $\Delta\delta = 9' 15''.0$
July 2. Comet smaller and more condensed: somewhat brighter, owing to the condensation.

Mt. Hamilton, 1889 *July* 3.

THE DEDUCTION OF PLANETARY MASSES FROM THE MOTIONS OF COMETS.

By A. HALL.

The laborious and interesting investigations of Backlund and Haerdtl on comets of short period, namely, Encke's and Winnecke's, and the results found by these astronomers for the masses of planets, brings up the question whether the motions of such bodies can be used for accurate determinations of these masses. For some time this has seemed to me a doubtful point.

In his last memoir Backlund has reduced the coefficient of the resisting medium in space to one-half the value found by Encke, and he finds a mass of *Mercury* three or four times greater than that found by Encke from this motion of the same comet. This value of the mass would give this planet the density of lead. Dr. v. Haerdtl finds in the motion of the Winnecke comet no evidence of a resisting medium in the regions traversed by this comet. In fact, there is a small retardation, and to remove this the mass of *Jupiter* has been slightly increased.

The objection to deducing values of planetary masses from the motions of comets consists, I think, in the fact that apparently other forces than that of gravitation act on these bodies. As a comet approaches the sun it changes form, disintegrates, and matter is thrown off to form a tail. Until we know more of the theory of these changes the computation of masses from the motions of comets, and inferences about the resisting medium in space, must be uncertain.

1889 *June* 10.

OBSERVATIONS OF COMET *e* 1888,

MADE AT THE U.S. NAVAL OBSERVATORY, WITH THE 9.6-INCH EQUATORIAL,

BY PROF. E. FRISBY.

[Communicated by the Superintendent.]

1889 Washington M.T.	*	No. Comp.	☄ — * $\Delta\alpha$	☄ — * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ	Obs.
d h m s			m s	′ ″	h m s	° ′ ″			
June 5 13 46 52.9	1	19 , 4	—2 9.75	— 4 27.6	22 47 6.01	+2 40 19.1	*n*9.612	0.729	F
6 13 6 3.2	2	20 , 4	—2 24.65	— 0 53.4	22 45 18.36	+2 39 43.5	*n*9.633	0.733	F
13 6 3.2	1	15 , 4	—3 57.86	— 4 59.5	22 45 17.86	+2 39 47.4	*n*9.633	0.733	F
23 12 2 3.5	3	20 , 4	—0 52.63	—10 8.1	22 5 47.81	+2 1 10.2	*n*9.593	0.732	F

Mean Places for 1889.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	22 49 15.32	{ +0.44 } { +0.40 }	+2 44 47.3	{ —0.6 } { —0.4 }	Bonn VI, +2°4581
2	22 47 42.60	+0.41	+2 40 37.4	—0.5	Bonn VI, +2°4577
3	22 6 39.30	+1.14	+2 11 14.9	+3.4	½(Grant + Lamont)

COMET *d* 1889.

A dispatch received July 7 from Mr. W. R. BROOKS at Geneva, N.Y., announces the discovery of a rather faint comet, observed by him as follows:

1889 July 6^d 12^h 30^m Wash. M.T. $\alpha = 23^h\ 45^m$, $\delta = -9°\ 10'$ Daily motion, $+1^m$ in α, and 5′ northward.

From alignments made by Mr. BROOKS, the more accurate position is obtained,

July 6^d 14^h Wash. M.T. $\alpha = 23^h\ 44^m\ 8^s$, $\delta = -9°\ 9'$

Mr. BARNARD telegraphs an observation from the Lick Observatory:

1889 July 8.9561 Greenw. M.T. $\alpha = 23^h\ 46^m\ 26^s.1$, $\delta = -8°\ 55'\ 57''$

He describes the comet as 1′ in diameter, slightly elongated, and 11^M or fainter.

The very unfavorable weather for the last ten days has prevented any observations in the eastern states.

A dispatch from Rochester, N.Y., July 6, announced the discovery of a comet by SWIFT in the position,

1889 July 5^d 15^h Wash. M.T. $\alpha = 22^h\ 52^m\ 28^s$, $\delta = +0°\ 49'$ Daily motion, -2^m in α, and 10′ southward.

A subsequent dispatch, received July 7, corrects this right-ascension to $21^h\ 27^m\ 30^s$, and also gives a later right-ascension, 1889 July 6^d 12^h 30^m Wash. M.T. $\alpha = 21^h\ 24^m\ 20^s$

These positions are sufficiently near to those of the comet *c* 1888 (*A.J.* IX, 23) to make it evident that this was the object seen.

NOTICE.

Prof. WILLIAM HOOVER of the Ohio University, Athens, Ohio, asks that any existing observations of the Comet 1886 IX may be soon published, inasmuch as he desires to make a definitive determination of the orbit.

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ON THE LIGHT-VARIATIONS OF *U CEPHEI.*

BY S. C. CHANDLER.

In the excellent discussion of this variable by Dr. J. WILSING (*A.N.* 2596), it was shown that the period of $2^d\ 11^h\ 49^m\ 43^s.5$, deduced from the eighteen minima afforded by his own observations, from 1881 Nov. 16 to 1884 April 9, not only satisfied those data, but also, when compared with the work of other observers, revealed no systematic differences, exceeding the uncertainties of observation and reduction, which could give rise to assumptions of irregularity in the period itself. Mr. G. KNOTT, too, from twenty of his own minima, covering a somewhat longer interval (1880 Oct. 23 to 1884 March 20), obtained $2^d\ 11^h\ 49^m\ 42^s.96$. A third series of twenty minima by SCHMIDT, nearly contemporaneous with the others (1880 Oct. 18 to 1883 Nov. 4), gives, according to my computation, $2^d\ 11^h\ 49^m\ 43^s.72$. For convenience, referring the various elements to the same principal epoch and meridian, we have:

Observer	Mean Epoch	Greenwich M.T. d h m	d h m s
SCHMIDT	172	1881 Nov. 21 8 28.3	+2 11 49 43.72 (*E*—207)
WILSING	207	1881 Nov. 21 8 18.8	+2 11 49 43.50 (*E*—207)
KNOTT	267	1881 Nov. 21 8 31.0	+2 11 49 42.96 (*E*—207)

These determinations, based on series of observations each of which is homogeneous in itself and entirely independent of the others, assign values to the period which are very accordant, well within the limits of their probable uncertainties.

In 1887 and 1888 I obtained two hundred and fourteen observations of this star, giving accurate times for ten minima, and an eleventh imperfectly. Comparison with the earlier elements showed that the period for the interval must be about a second and a half greater than the above values. The period $2^d\ 11^h\ 49^m\ 45^s.00$, and an epoch formed from all my observations, were therefore provisionally adopted as the elements in my catalogue of 1888, with the intention to make a more thorough investigation for use in its next edition. This intention has been since carried out, and the results are communicated in this paper, — wherein I think it is demonstrated, first, that the period is not uniform: secondly, that the rate of variation is itself irregular, so that, while the period has been increasing during the last sixty years at a mean rate of about two thousandths of a second between successive minima, the increase during the current decade has been far more rapid than previously, or at the rate of over six thousandths of a second from minimum to minimum; thirdly, that, in addition to this secular lengthening of the period, there is good evidence of a periodical irregularity which is of far less amplitude, and which completes its cycle in perhaps a few hundred periods. The third conclusion, however, is not certain, and its establishment must be left for future observation.

The fact of the lengthening of the period, while it is manifest from the modern observations alone, is abundantly confirmed by some older ones, which have heretofore escaped the attention of investigators. They furnish a minimum sixty-two years, or nearly eight thousand periods, anterior to the discovery of the star's variability, and require careful attention, from their high importance. They consist of four estimates of magnitude in the meridian instrument by SCHWERD at Speyer, in 1827–28, as follows:

1827 Dec. 11	U.C.	Estim. mag. =	8
1828 Mar. 11	L.C.		6.7
Mar. 12	L.C.		8
May 12	L.C.		10

The last of these arrests notice. SCHWERD, it may be remarked, was in general an accurate observer of stellar magnitudes, although his scale differs from ARGELANDER'S. At 6^M his estimates of magnitudes are numerically smaller, and at 10^M greater, than those of the *Durchmusterung*, by about a half a unit in each case. If we take the differences between his magnitudes and those of the DM. for the stars observed on these four nights a little while before and after the variable, we find, after applying the systematic corrections for scale, no discordance greater than $0^{\rm M}.5$, and an average difference of only $0^{\rm M}.21$, which is the effect of the combined error of both authorities. Unless we are prepared to admit the probability of an error of considerably more than two magnitudes in the estimate of 1828 May 12, which I consider to be out of the question — it follows necessarily, from the known character of the light-curve, that the star could not then have been over four hours from a minimum, and with a high degree of probability was not more than an hour and a half therefrom. This degree of uncertainty does not sensibly detract from the value of the observation in the determination of the period. I have therefore assumed the minimum

Epoch — 7636. 1828 May $12^{\rm d}$ $9^{\rm h}$ Greenwich M.T.,

and its bearing upon the investigation will be presently discussed.

The star was also observed by Lalande on 1790 March 30 (Fedorenko 145), as $8^{\rm M}$; which corresponds to $7^{\rm M}.4$, the estimates for this zone being systematically faint by an average amount of $0^{\rm M}.6$. The variable was therefore very probably at or near maximum at midnight of this date; an indication which may prove serviceable, when the law of irregularity in the period is a little better known, in excluding expressions which might assign a minimum near this epoch. It cannot now be utilized.

Further it may be said that, as neither of Carrington's three observations, on 1855 Dec. 19, 21 and 30, falls on a date when a minimum could have occurred, they have no significance in this connection.

In the following investigation only those observations have been used of which sufficient details are in hand to assure their reference to a common zero-point. More is lost than gained by including data which cannot be homogeneously reduced; the danger of obscuring the actual phenomena being greater than the barren advantage of fullness of material. The reasons for this course will be found in the remarks on page 166, Vol. VII, of this Journal, a reference to which saves repetition here. The principle in question has indeed more force in the present case, on account of peculiar circumstances which tend to introduce subjective errors in the light-curves, and perhaps in the times of minima deduced from the two series — alternating in the spring and autumn months, in reversed positions of this circumpolar star. This subject will receive particular notice later in the article.

Fortunately Wilsing has given the individual magnitudes for his fine series of observations. My own series has been reduced by a light-scale practically identical with his. Mr. Yendell has kindly furnished me with the details of two minima determined by him in 1888 and 1889; and for one of Schmidt's minima we have (*A.N.* 98,283) means for a reduction uniform with the others. Moreover we can introduce with entire safety (correcting an error of one hour in all the published times) five minima observed at the Harvard College Observatory in 1881; a comparison of the light-curve, there deduced with Wilsing's and my own, showing the instant of minimum to be sensibly coincident in all three. On these four series, therefore, together with Schwerd's minimum of 1828, I have based the elements here derived. The only remaining data that I know of, are those of Schmidt (with the above exception), Knott, the Baxendells (four by the father, one by the son), and an incomplete one by Glasenapp. These can be employed when we have the original observations, or a sufficient guide to the manner of arriving at the published times of minima. We possess indeed some hints on this point in the case of Schmidt, although not enough for safe use of his results as a whole.

My own observations have been reduced with the following light-scale:

	L	Mag.		L	Mag.
k	32	6.64	*m*	12	8.57
p	19	7.90	*h*	11	8.67
e	18.5	7.95	*a*	8	8.97
f	18	8.00	*d*	1	9.35
g	12	8.57	*b*	3	9.45

The places of the comparison-stars will be found on page 188 of Vol. VII. The relation between L and M is defined by the expression $M = 9^{\rm M}.45 \pm 0^{\rm M}.097\,(3-L)$. From a plotting of the observations on each evening, the times were read off at which the variable attained the magnitudes 8.0, 8.3, 8.6 and 8.9, during decrease and increase. To the mean of these times, for each point, was applied the correction (see p. 53) to reduce to the true minimum, as afterwards determined in the discussion of the light-curves. The mean of the results, without weights for the proportional velocity of the light-variations, was taken as the time of minimum. An example will make this process clear.

1887 Nov. 6, Camb. M.T.

Mag.	Before	After	Corr.	Minimum
	h m	h m	m	h m
8.0	7 51.0	12 54.0	0.0	10 22.5
8.3	8 33.0	12 41.0	—7.5	29.5
8.6	8 54.4	12 21.0	—5.7	32.0
8.9	9 20.4	11 42.0	+0.3	10 31.5
Camb. M.T. of minimum.		1887 Nov. 6,		10 28.9

The results, reduced to the Greenwich meridian, are given in the following table of minima.

The minima by the other observers were treated in a precisely similar way; applying in the case of Wilsing, however, the corrections to the middle times resulting from his light-curves (p. 53). A comparison of these times with those given by him indicating that no certainly appreciable systematic difference existed (the mean differences being only $-0^{\rm m}.36$ and $-0^{\rm m}.31$, respectively, for the November and March minima), I adopted his times unchanged, excluding dates where all the observations were on one side of minimum. Such incomplete minima it does not seem to me safe to use for this purpose.

In the table below are placed all the minima, as thus determined, with their deviations from the elements of my catalogue, in column I, of (O—C). These elements appear to represent the observations since 1880 as well as any assumption of a uniform period will do. But they are incompatible with SCHWERD's minimum, and reveal besides systematic variations in the others, indicating an increase of period.

TABLE OF MINIMA.

Epoch	Observed Minimum Greenwich M.T.	Red to ⊙	(O—C) I	(O—C) II	(O—C) III	p	Observer
	d m s	m	m	m	m		
—7636	1828 May 12 9 0		+1005.0	— 0.9			Schwerd
+ 43	1880 Oct. 8 12 32.7	+2.1	+ 9.8	+12.6	+4.0	3	Schmidt
92	1881 Feb. 7 16 2.7	+1.4	+ 1.4	+ 5.0	—1.4	3	H. C. O.
96	Feb. 17 15 21.7	+1.8	+ 1.8	+ 5.4	—0.7	3	"
98	Feb. 22 15 1.7	+0.4	+ 0.8	+ 4.4	—1.6	3	"
110	Mar. 24 13 0.9	—1.5	+ 1.2	+ 5.0	—0.5	3	"
114	Apr. 3 12 20.3	—2.0	+ 1.0	+ 4.9	—0.4	3	"
205	Nov. 16 8 37.8	+3.5	— 3.2	+ 1.9	—0.7	2	Wilsing
209	Nov. 26 8 2.4	+3.7	+ 2.3	+ 7.4	+6.0	2	"
252	1882 Mar. 13 12 43.2	—0.8	— 0.3	+ 5.2	+5.4	1	"
254	Mar. 18 12 18.8	—1.1	— 4.5	+ 1.0	+1.3	4	"
256	Mar. 23 11 56.7	—1.4	— 6.4	— 0.8	—0.5	3	"
321	Sept. 1 12 41.9	—0.1	—10.7	— 4.5	—2.2	2	"
327	Sept. 16 11 37.5	+0.8	—15.7	— 9.5	—7.0	2	"
400	1883 Mar. 17 11 12.7	—1.0	—14.1	— 7.4	—3.1	2	"
463	Aug. 21 12 25.7	—0.8	—15.1	— 8.1	—2.5	2	"
465	Aug. 26 12 7.0	—0.5	—13.0	— 6.0	—0.4	2	"
467	Aug. 31 11 43.1	—0.2	—16.1	— 9.1	—3.4	2	"
471	Sept. 10 11 8.1	+0.5	— 9.4	— 2.4	+3.4	2	"
546	1884 Mar. 15 10 17.7	—0.9	—12.4	— 5.2	+1.6	4	"
551	Apr. 4 8 57.2	—2.1	—12.2	— 5.0	+1.9	1	"
1078	1887 Nov. 1 15 33.3	+3.1	+ 0.1	+ 3.6	+5.1	2	Chandler
1080	Nov. 6 15 13.1	+3.3	+ 0.9	+ 4.4	+5.8	4	"
1084	Nov. 16 14 30.9	+3.5	— 0.4	+ 5.1	+4.5	1	"
1086	Nov. 21 14 4.7	+3.6	— 5.9	— 2.5	—1.4	2	"
1090	Dec. 1 13 25.7	+3.7	— 3.8	— 0.5	+0.7	4	"
1092	Dec. 6 13 3.5	+3.7	— 5.5	— 2.2	—1.0	3	"
1096	Dec. 16 12 25.0	+3.6	— 3.2	+ 0.1	+1.0	4	"
1133	1888 Mar. 17 18 7.5	—1.0	— 6.0	— 3.3	—3.7	2	"
1141	Apr. 6 16 7.1	—2.2	— 5.6	— 3.0	—3.7	4	"
1145	Apr. 16 16 10.3	—2.7	— 1.9	+ 0.6	—0.2	4	"
1216	Oct. 10 15 58.8	+2.2	— 0.7	+ 0.5	—3.0	4	Yendell
1299	1889 May 5 13 58.2	—3.4	+ 3.8	+ 3.3	—4.0	1	"

Forming five normal epochs we have:

	p	Minima included	Mean Epoch	(O—C) I	(O—C) II	(O—C) III
				m	m	m
I	0.5		—7636	+1005.0	—0.9	
II	18	43– 114	+ 92	+ 2.67	+6.25	—0.10
III	16	205– 327	260	— 5.76	—0.12	+0.29
IV	15	400– 554	485	— 13.15	—6.09	—0.11
V	35	1078–1294	+1125	— 2.68	+0.12	+0.04

From these we get values of the period corresponding to the middle of the respective intervals, as follows:

	Middle Epoch	Period
		d h m s
I – II	—3772	2 11 49 37.73
II –III	+ 176	2 11 49 41.99
III–IV	+ 372.5	2 11 49 43.03
IV – V	+ 805	2 11 49 45.97

The evidence of a progression in these values is distinct, the differences being many times greater then the probable uncertainties. A lengthening of the period may be regarded as demonstrated; and it is equally clear that the rate of increase is not uniform. From all the normals we find the elements,

(*a*) 1880 June $23^d\ 7^h\ 43^m.65$ (Greenw.)
$+ 2^d\ 11^h\ 49^m\ 43^s.95\ E + 0^s.00090\ E^2$

But, omitting SCHWERD's minimum, the last four normals alone give,

(*b*) 1880 June $23^d\ 7^h\ 54^m.65$ (Greenw.)
$+ 2^d\ 11^h\ 49^m\ 40^s.70\ E + 0^s.00327\ E^2$

Thus during the last ten-years the rate of increase has been nearly four times as great as for the whole interval from 1828; that is $0^s.0065$ from minimum to minimum by elements (*b*), against $0^s.0018$ by (*a*). In the columns II and III, of

(O—C), are given the deviations from elements (*a*) and (*b*), respectively.

It is manifest that a representation of the whole series of observations would require an inconvenient number of terms depending on powers of the epoch. It is probable that the observed variation from uniformity of period is only a partial development of a very long inequality, whose coefficients cannot be assigned now with any certainty, but whose duration must be at least twenty thousand periods of the star. A further scrutiny of the residuals raises a suspicion that there is also a small inequality completing its course in a few hundreds of periods. This cannot be confidently asserted, however, until assiduous observation of the star for several years shall have removed a doubt whether it may not be due simply to some form of systematic subjective error. Nevertheless, the first explanation appears more probable, and receives support from the fact that analogous terms exist pretty certainly in the case of *Algol* (A.J., VII, pp. 170, 2.)

We come now to the discussion of the light-curve. All my observations, 214 in number, were assembled in the usual manner, keeping the comparisons in March and April separate from those in November and December, in order to inquire into the peculiarities which Knott and Wilsing have noticed in their results. The magnitude at maximum appears to be $7^M.21$, from a few observations taken from ten to twenty hours away from minimum. The magnitude at minimum, for the ten determinations of it, is:

		M			M
1888	Mar. 17	9.29	1887	Nov. 1	9.22
	Apr. 6	9.22		Nov. 6	9.12
	Apr. 16	9.29		Nov. 16	9.18
				Nov. 21	9.15
				Dec. 1	9.21
				Dec. 6	9.19
				Dec. 16	9.15
	Mean	9.27		Mean	9.17

The means of the magnitudes within an hour of minimum, from my light-table hereafter given, give 9.27 and 9.14, respectively, for the spring and autumn periods, agreeing substantially with the above values. While there thus appears to be some indication of systematic difference, it is by no means so striking as in the case of Knott and Wilsing, as the following comparison shows:

	Chandler	Knott	Wilsing
In the Spring months	9.27	9.43	9.20
In the Autumn months	9.17	9.18	8.76
Difference	0.10	0.25	0.44

Nor do I think, as those gentlemen seem to do, it can be reasonably attributed to a real difference in the behavior of the star, but far more naturally to a subjective effect of the reversal of the position of the variable, with reference to its comparison-stars at the two epochs. This physiological source of error has been a matter of common knowledge, time out of mind, and it is not because I have neglected the customary and obvious precautions taken by experienced observers, to eliminate it as much as possible from the results of the observations, that a trace of it still remains in this case; but because the effective application of these precautions is difficult in stars near the pole.

The form of the light-curve by my observations is shown in the column *C* of the following table. For comparison, the values obtained by Wilsing, whose scale is practically identical, are given under *W*: and also those of the Harvard College observations, reduced to this scale by the relation $H = 10.27 - 0.8333\,h$, where *h* represents the published magnitudes on the scale there used. It should be remarked that my spring curve rests on only 54 observations, and is therefore much less certain than the autumn one, based on 159 observations; and also that, as the series was primarily undertaken merely to get times of minima, very few comparisons were made more than three hours away from that point; consequently the beginning and ending of the star's whole variation are not defined.

Comparative Light-Table.

Time from minimum	Spring			Autumn	
	C	W	H	C	W
h m	M	M	M	M	M
—4 0	–	–	7.49	7.46	–
3 50	–	–	–	7.50	–
3 40	7.59	–	–	7.55	–
3 30	7.66	–	7.61	7.61	–
3 20	7.73	–	–	7.67	–
3 10	7.79	–	–	7.73	–
3 0	7.86	–	7.78	7.80	–
2 50	7.93	–	–	7.87	7.70
2 40	8.00	–	–	7.93	7.77
2 30	8.08	–	8.06	8.00	7.86
2 20	8.18	8.06	–	8.07	7.95
2 10	8.29	8.26	–	8.13	8.04
2 0	8.43	8.47	8.50	8.21	8.13
1 50	8.57	8.66	–	8.30	8.22
1 40	8.73	8.81	–	8.41	8.32
1 30	8.93	8.95	8.85	8.57	8.43
1 20	9.07	9.07	–	8.82	8.56
1 10	9.20	9.16	–	9.01	8.70
1 0	9.27	9.19	9.21	9.11	8.79
0 50	9.29	9.20	–	9.15	8.80
0 40	9.28	9.20	–	9.21	8.80
0 30	9.27	9.20	9.24	9.20	8.80
0 20	9.27	9.20	–	9.18	8.80
—0 10	9.27	9.20	–	9.17	8.80
0 0	9.27	9.20	9.24	9.16	8.80
+0 10	9.26	9.20	–	9.15	8.80
0 20	9.26	9.20	–	9.13	8.80
0 30	9.26	9.20	9.24	9.12	8.80
+0 40	9.27	9.20	–	9.10	8.80

Time from minimum	Spring			Autumn	
	C	W	H	C	W
h m	M	M	M	M	M
+0 50	9.27	9.20	–	9.07	8.78
1 0	9.25	9.20	9.22	9.04	8.78
1 10	9.21	9.17	–	8.99	8.71
1 20	9.10	9.08	–	8.86	8.63
1 30	8.85	8.93	8.88	8.72	8.55
1 40	8.60	8.74	–	8.60	8.47
1 50	8.39	8.56	–	8.47	8.39
2 0	8.23	8.34	8.39	8.36	8.34
2 10	8.10	8.13	–	8.24	8.22
2 20	7.97	7.94	–	8.12	8.13
2 30	7.88	–	7.97	8.00	8.04
2 40	7.79	–	–	7.89	–
2 50	–	–	7.66	7.79	–
3 0	–	–	7.66	7.70	–
+3 30	–	–	7.48	7.42	–

The salient feature of this table is the satisfactory accord of the three curves for the spring months; the slight differences at minimum being, quite likely, due to imperfect reduction to a uniform scale. The general rates of increase are alike in all, and the same is true for the decrease. All agree, too, in a more rapid rate of increase than of decrease. It will be recollected that Schmidt arrived at a similar result from a portion of his observations. Notwithstanding this unanimity, I am far from feeling sure that the fact is so. The two autumn curves contradict it; and, as the case stands, we have no reason to prefer one to the other. The contradiction probably originates in the same way as the difference in the minimum magnitudes, already treated of. During the time required by the star to complete its changes, its parallactic angle alters by about 120°. The group of comparison-stars used when it is above its mean brightness is in an opposite direction, as regards the variable, from the group used in its fainter stages. In March and April this brighter group is, at the beginning of a night's work, below and at the end, horizontally to the right of the variable, in an inverting telescope. In November and December it is above at the beginning, and horizontally to the left at the end. For the fainter group all these conditions are reversed. It is easy to see that this state of things may effect the apparent rates of change downward and upward differently; and we must be cautious in inferences as to the actual nature of the variations until this doubt is removed. To the solution of this question, observation must in future be especially addressed. As soon as practicable, later in the year, it is proposed to make independent comparisons with erecting and inverting eyepieces, and with a reversing prism, on the same telescope. This ought to determine whether the phenomenon is merely subjective, and serve to eliminate the error.

Another important matter is the form of the light-curve near minimum. My observations do not make this entirely flat, but place its lowest point at the end of the period of rapid decrease, three-quarters of an hour before the middle of the nearly stationary interval at minimum; a similar peculiarity to that of *S Cancri*, according to Schönfeld's curve. This may be subjective, but it is not proper to assume it to be so, nor to treat the observations so that it escapes attention. I suspect that the combination of the Harvard College observations in half-hourly groups, while it has certainly helped to diminish the discordance of the mean values, and gives an apparently smoother curve, may have overslaughed a feature of this sort.

In conclusion I give the corrections employed on page 50 in getting the times of minima for my own and Wilsing's observations. They were found by taking the half-differences, with the opposite sign, of the times, by the above light-table, when the star was at the four points of brightness indicated. Similar values are added for the curve *H*, to show that the minimum-point by all three authorities, lies in the same direction, and by nearly the same amount, from the middle times.

Mag.	Spring			Autumn	
	C	W	H	C	W
	m	m	m	m	m
8.0	+11.0	+3.3	+2.2	0.0	−10.0
8.3	+ 6.9	+3.0	+3.2	−7.5	− 9.5
8.6	+ 3.9	+2.5	+4.5	−5.7	− 3.3
8.9	+ 1.3	+0.5	+3.7	+0.3	
Mean	+ 5.8	+2.1	+3.1	−3.2	− 7.6

In a subsequent number will be printed an ephemeris based on the elements heretofore given, constructed on the same plan as those for *Algol* and *U Ophiuchi* (Vol. VII, pp. 139, 182.) It is hoped that observers will be stimulated to share in the solution of the interesting problems which the observation of this star presents.

Cambridge, 1889 *July* 18.

ON THE FORCE TO ANY POINT IN A CONIC.

BY S. HIRAYAMA

The question first proposed by M. Bertrand is as follows: "Knowing that a material point under the action of a central force always describes a conic, it is required to find the expression of that force." The subject is very interesting in connection with double-star problem, as was shown by Prof. Hall in the *Astr. Journal*, Vol. VIII, No. 9. M. Darboux used the polar coordinates in the solution of the problem. Mr. Glaisher solved the problem geometrically, while M. Halphen and Zessland took the general differential of conics. The results at which they have arrived are all the same.

namely, that there are two general expressions for the central force. The most general way of treating the problem will be the last method, and it is also this method that I now describe. The result at which I have arrived is not new.

Calling R, the central force acting in the line joining two bodies, we have for the equation of the motion

$$(1)\qquad \frac{d^2x}{dt^2}+R\frac{x}{r}=0 \qquad \frac{d^2y}{dt^2}+R\frac{y}{r}=0$$

whose first integral is

$$(2)\qquad x\frac{dy}{dt}-y\frac{dx}{dt}=H \text{ (a constant)}$$

We are to find R so that (1) shall satisfy the general differential equation of conics. Let the general equation of the conic be

$$(3)\qquad ax^2+2hxy+by^2+2gx+2hy+c=0$$

we have the following well known differential equation, given first by MONGE.

$$(4)\qquad 9\left(\frac{d^2y}{dx^2}\right)^2\frac{d^5y}{dx^5}-15\frac{d^2y}{dx^2}\frac{d^3y}{dx^3}\frac{d^4y}{dx^4}+40\left(\frac{d^3y}{dx^3}\right)^3=0$$

But we may write this in the following simple form:

$$(5)\qquad \frac{d^3}{dx^3}\left\{\left(\frac{d^2y}{dx^2}\right)^{-2/3}\right\}=0$$

If we develop (5) then we can get (4). or we may prove it thus: —

From (3)

$$by=-(hx+f)\pm[(h^2-ab)x^2+2(hf-bg)x+(f^2-bc)]^{1/2}$$

Operate on both sides by $\left(\frac{d}{dx}\right)^2$, then we get the form,

$$\frac{d^2y}{dx^2}=\pm\frac{d^2}{dx^2}\left\{Ax^2+2Bx+C\right\}^{1/2}=\pm\frac{AC-B^2}{(Ax^2+2Bx+C)^{3/2}}$$

That is $$\left(\frac{d^2y}{dx^2}\right)^{-2/3}=\pm(AC-B^2)^{-2/3}(Ax^2+2Bx+C).$$

Hence we get (5) $$\frac{d^3}{dx^3}\left\{\left(\frac{d^2y}{dx^2}\right)^{-2/3}\right\}=0$$

Similarly solving (3) as to y, we can get

$$(6)\qquad \frac{d^3}{dy^3}\left\{\left(\frac{d^2x}{dy^2}\right)^{-2/3}\right\}=0$$

Now $\frac{dy}{dx}=\frac{\frac{dy}{dt}}{\frac{dx}{dt}}$, $\frac{d^2y}{dx^2}=\frac{\frac{d^2y}{dt^2}\frac{dx}{dt}-\frac{d^2x}{dt^2}\frac{dy}{dt}}{\left(\frac{dx}{dt}\right)^3}$ Substituting here (1) and (2) we get

$$\frac{d^2y}{dx^2}=\frac{HR}{r}\left(\frac{dx}{dt}\right)^{-3}$$

Hence (5) becomes $$\frac{d^3}{dx^3}\left\{\left(\frac{HR}{r}\right)^{-2/3}\left(\frac{dx}{dt}\right)^2\right\}=0$$

Put for a moment

$z=\left(\frac{HR}{r}\right)^{1/3}$, then this becomes $\frac{d^3}{dx^3}\left\{\left(\frac{1}{z}\frac{dx}{dt}\right)^2\right\}=0$

Call the solution of this differential equation by P, which contains x in no higher power than two, then

$$\frac{1}{z}\frac{dx}{dt}=\sqrt{P} \qquad (7)$$

Similarly from (6) $$\frac{1}{z}\frac{dy}{dt}=\sqrt{Q} \qquad (8)$$

where Q is known to contain y in no higher power than two.

From the last two, we get

$$z=\frac{H}{x\sqrt{Q}-y\sqrt{P}} \quad \text{but } z=\left(\frac{HR}{r}\right)^{1/3} \text{ so that}$$

$$R=\frac{H^2r}{(x\sqrt{Q}-y\sqrt{P})^3} \qquad (9)$$

Also from (7) and (8) $\sqrt{Q}\,dx-\sqrt{P}\,dy=0$ which much must satisfy the equation

$$(ax+hy+g)\,dx+(hx+by+f)\,dy=0$$

Hence $$\frac{dy}{dx}=\frac{\sqrt{Q}}{\sqrt{P}}=-\frac{ax+hy+g}{hx+by+f} \qquad (10)$$

Also from this.

$$\frac{x\sqrt{Q}-y\sqrt{P}}{\sqrt{P}}=\frac{-(ax^2+2hxy+by^2+gx+fy)}{hx+by+f}=+\frac{gx+hy+c}{hx+by+f}$$

Hence (11)

$$R=\frac{+H^2r}{(gx+fy+c)^3}\frac{(hx+by+f)^3}{P^{3/2}}=\frac{-H^2r}{(gx+fy+c)^3}\frac{(ax+hy+g)^3}{Q^{3/2}}$$

Now as the particular solution of (10) we have

$$\sqrt{Q}=-\lambda(ax+hy+g), \qquad \sqrt{P}=\lambda(hx+by+f)$$

where λ = a certain constant.

Hence we have for the expression of R

$$R=\frac{\lambda H^2r}{(gx+fy+c)^3}$$

Also from the general equation of the conics we have

$$(gx+fy+c)^2=\{(g^2-ac)x^2+2(fg-hc)xy+(f^2-bc)y^2$$

Thus we get two general expressions for the central force R. Of course the value of R depends on the solutions of the differential equation $\sqrt{Q}\,dx-\sqrt{P}\,dy=0$; in fact, λ may be a variable, but so far as I can see now there is only one solution of λ, that is a constant, the differential equation being identified with

$$(ax+hy+g)dx+(hx+by+f)dy=0$$

Tokyo Observatory, Japan, 1889 *June* 13.

FILAR-MICROMETER OBSERVATIONS OF COMET *d* 1889 (*BROOKS, July 6*),

MADE WITH THE 12-INCH EQUATORIAL OF THE LICK OBSERVATORY,

BY E. E. BARNARD.

1889 Mt. Hamilton M.T.	*	No. Comp.	☄ — * $\Delta\alpha$	☄ — * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
d h m s			m s	′ ″	h m s	° ′ ″		
July 8 14 50 23	1	8 , 6	+3 21.48	—10 18.9	23 46 26.03	—8 55 57.1	*n*9.321	0.797
9 13 58 13	1	14 , 6	+4 20.13	— 4 31.9	23 47 24.72	—8 50 9.9	*n*9.474	0.758
10 14 37 54	1	8 , 6	+5 21.45	+ 1 29.6	23 48 26.06	—8 44 8.2	*n*9.342	0.792

Mean Places for 1889.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	23 43 3.51	(+1.04) +1.08 (+1.10)	—8 45 47.5	(+9.3) +9.5 (+9.7)	Weisse's Bessel 23^h 847

A very small stellar nucleus of 12^M. Tail 10′ long. Comet's equivalent brightness = 11^M – 12^M.

July 9. Position-angle of tail = 245°. One observation.

FILAR-MICROMETER OBSERVATIONS OF COMET *c* 1889 (*BARNARD, June 23*).

MADE WITH THE 12-INCH EQUATORIAL OF THE LICK OBSERVATORY.

BY E. E. BARNARD.

1889 Mt. Hamilton M.T.	*	No. Comp.	☄ — *		☄'s apparent		log *p*Δ	
			Δα	Δδ	α	δ	for α	for δ
d h m s			m s	′ ″	h m s	° ′ ″		
July 3 14 4 28	9	16 , 6	+2 7.34	+0 1.4	2 7 53.16	+43 49 51.6	*n*9.803	0.450
4 13 57 27	10	14 , 7	—1 12.02	+2 8.5	2 12 32.56	+44 13 53.0	*n*9.816	0.562
5 13 53 28	11	12 , 8	—2 3.22	+1 9.6	2 17 11.95	+44 36 18.5	*n*9.814	0.497
7 14 33 25	12	18 , 8	—0 57.81	—5 8.4	2 26 37.70	+45 20 37.0	*n*9.803	0.348
9 15 15 49	13	10 , 8	—0 54.79	—6 55.5	2 35 57.6	+45 59.8	*n*9.775	0.155
10 15 19 39	14	3	–	—1 8.7	–	+46 18 28.6	–	0.061
15 28 32	14	10	—0 2.95	–	2 40 35.59	–	*n*9.764	–

Mean Places for 1889.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
9	2 5 45.66	+0.16	+43 49 59.3	— 9.1	Weisse's Bessel II. 52
10	2 13 44.45	+0.13	+44 11 53.5	— 9.0	Compared with Σ249
11	2 19 15.05	+0.12	+44 35 49.0	—10.1	Lalande 4438
12*	2 27 35.37	+0.14	+45 25 55.5	—10.1	Compared with Oe. Arg. 2912
13	2 36 52.2	+0.16	+46 6.9	—10.2	DM. +45 656
14	2 40 38.38	+0.16	+46 19 47.5	—10.2	Comp. with Bonn Beobb. +46°622

*This is Oe. Arg. 2903. The catalogue R. A. is in error by one thread-interval = —13.53.

July 10. Observations very difficult, but good. Comet seen only for a few minutes between moonset and dawn. This is the last observation of the comet that can be made until the moon withdraws, if it can then be observed.

Star-Differences.

Stars	No. Comp.	Δα	Δδ	Stars	No. Comp.	Δα	Δδ
		m s	′ ″			m s	′ ″
No. 5 — W.B. I. 1182	6.3	—1 17.87	—0 51.1	No. 12 — Oe. Arg. 2912	8.2	—0 35.88	—0 51.4
10 — Σ249	6.3	—0 48.28	+6 25.9	14 — Bonn Beobb. 46°622	6.2	+3 28.77	—2 36.9

OBSERVATIONS OF COMET *e* 1888,

MADE AT THE U.S. NAVAL OBSERVATORY WITH THE 9.6-INCH EQUATORIAL.

BY PROF. E. FRISBY.

[Communicated by the Superintendent.]

1889 Washington M.T.	*	No. Comp.	☄ — *		☄'s apparent		log *p*Δ		Obs.
			Δα	Δδ	α	δ	for α	for δ	
d h m s			m s	′ ″	h m s	° ′ ″			
July 5 11 50 21.9	1	20 , 4	—0 24.96	— 4 22.0	21 28 0.10	+0 18 57.2	*n*9.471	0.736	F
6 12 16 32.8	2	20 , 4	—1 28.69	— 4 1.3	21 24 29.60	+0 11 22.9			
6 12 16 32.8	1	20 , 1	—3 55.99	—12 12.6	21 24 29.39	+0 11 6.7	*n*9.382	0.737	F
8 13 21 15.0	3	11 , 3	+0 11.18	— 8 30.4	21 17 17.56	+0 21 53.5	*n*8.967	0.739	F

Mean Places for 1889.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place.	Authority
	h m s	s	° ′ ″	″	
1	21 28 23.71	(+1.62) (+1.64)	+0 53 13.1	(+6.1) (+6.2)	⅓(Lamont + H.C.Z. 110 and 141)
2	21 25 56.65	+1.64	+0 15 20.9	+6.3	⅓(Lamont + H C.Z. 56 and 57)
3	21 17 4.66	+1.72	+0 33 17.2	+6.7	⅓(Lamont + H.C.Z. 67 and 68)

Lamont's position for star 2 is 1′ wrong. On comparing positions of comet this star appears to have a proper motion, or possibly 1 rev. = 15″.3 wrong.

COMET *d* 1889.

The continual cloudiness, except during those nights when it was near the bright moon, has almost entirely prevented observations of this comet (Brooks, *July 6*). Mr. Chandler, however, gives two, and has deduced an orbit and ephemeris, as follows. He says:

"Bad weather and moonlight prevented my observing the comet until July 20 and 21. It was then an excessively faint object in my 5-inch telescope, and the following ring-micrometer positions are of course very uncertain.

Cambridge M.T.	App. R.A.	App. Decl.
d h m s	h m s	° ′ ″
1889 July 20 14 56 52	23 57 6.74	−7 51 25.0
21 13 34 23	57 45.35	−7 46 54.9

Mr. W. M. Reed kindly assisted as recorder.

From Barnard's positions of July 8 and 10, and my own of July 20 combined with one of the same date kindly sent me from the Harvard College Observatory by Mr. Wendell, I get the following rough elements, in which the perihelion is quite uncertain. The small inclination and direct motion make it almost certain that the comet will prove to be one of short period."

$$
\begin{aligned}
T &= 1889 \text{ Aug. } 3.402 \text{ Gr. M.T.} \\
\omega &= 311^\circ\ 24'.1 \\
\Omega &= 28\ \ 12\ .6 \\
i &= 5\ \ 55\ .3 \\
\log q &= 0.3628
\end{aligned}
$$

(C—O). $\Delta\lambda \cos\beta$, —0″.8; $\Delta\beta$, +5″.0

Ephemeris for Greenwich Mean Time.

1889	α	δ	log *r*	log Δ	Br.
	h m s	° ′			
July 27.5	0 1 55	−7 19	0.3630	0.1893	1.25
29.5	3 7	7 11			
31.5	4 13	7 3	0.3630	0.1806	1.30
Aug. 2.5	5 13	6 55			
4.5	6 8	6 48	0.3630	0.1721	1.35
6.5	6 58	6 41			
8.5	7 40	6 35	0.3633	0.1648	1.40
10.5	8 13	6 29			
12.5	8 40	6 23	0.3645	0.1590	1.43
14.5	8 58	6 18			
16.5	9 10	6 14	0.3664	0.1547	1.45
18.5	9 16	6 9			
20.5	0 9 16	−6 5	0.3689	0.1521	1.45

Mr. Wendell has observed the comet as follows at the Harvard College Observatory:

Greenwich M.T.	α	δ
d h m s	h m s	° ′ ″
1889 July 20 17 55 48	23 57 2.75	−7 51 9.1
23 17 50 57	23 59 16.06	−7 36 50.7

COMET *e* 1889.

A dispatch from Kiel announces the discovery of a bright comet by Davidson, at Queensland, and the position, 1889 July 22.9610 Greenw. M.T. $\alpha = 12^{\mathrm{h}}\,46^{\mathrm{m}}\,9^{\mathrm{s}}.0$, $\delta = -32^\circ\,29'\,6''$. Daily motion, $+11^{\mathrm{m}}$ in α, and 2° 48′ northward.

CORRIGENDUM.

No. 198. p. 45. Table XVII in the corrections for ″ put $^{\mathrm{s}}$

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Observations of Comet *e* 1888, by Prof. E. Frisby.
Comet *d* 1889.
Comet *e* 1889.
Corrigendum.

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PROPER-MOTIONS OF STARS IN THE ALBANY ZONE (+0° 50′ to 5° 10′ for 1855),

BY LEWIS BOSS.

The catalogue herewith presented contains 296 numbers, and 295 stars for which the amount and direction of proper-motion is computed. All these stars are situated in the Albany "A.G." zone, for which the limiting parallels are +0° 50′ and +5° 10′ of declination for 1855.0. This catalogue forms part of a larger list of proper-motions, to be published in the Albany catalogue (now in press), and includes all for which the annual proper-motion, as it results from the computation, is 0″.10 or greater. It may be proper to mention that an effort was made to have the list practically complete so far as existing data permit, but to include no proper-motion which rests upon a single observation at the older date, or even upon an unverifiable position from the mean of several observations. It may therefore be hoped that, while from the nature of the material, many of the proper-motions here presented are subject to errors of considerable amount, none are so grossly in error as to be entirely spurious.

These proper-motions were originally computed from positions reduced to the system of AUWERS's *Fundamental-Catalog*, and are so presented in the forthcoming Albany catalogue. The systematic corrections required for the computation made in this way are given by the writer in a previous article in the *Astr. Journal* (No. 195), to which the reader is referred for further information upon this and other points. These values of μ and μ' were converted into those presented in the present paper by the addition of $+0^s.0005$ and $-0''.013$ respectively, and are now supposed to conform to the present system of star-positions in the *American Ephemeris*. They are probably not sensibly different from those which would have been obtained if the systematic corrections (Table VII, *Astr. Jour.*, No. 196), necessary to reduce the various determinations to the *American Ephemeris*, had been employed in the first instance.

The authorities chiefly consulted for the computation of these proper-motions, with the abbreviation used for each, are:

Br. — AUWERS's reduction of BRADLEY's observations.

D'A. — GOULD's reduction of D'AGELET's observations.

LZ. — LALANDE's zones, reduced by means of VON ASTEN's tables.

Pi. — PIAZZI's catalogue.

BZ. — BESSEL's zones, reduced by means of LUTHER's tables in the Königsberg observations. Volume XXXVII.

Str. — STRUVE's *Positiones Mediae* for 1830.

R. — RUMKER's Hamburg catalogues for 1836 and 1850.

B.B. — ARGELANDER's observations, *Bonner Beobachtungen*, Band VI.

Sj. — SCHJELLERUP's catalogue.

Lam. — LAMONT's catalogues for 1850, for +3° to +9°, and —3° to +3° of declination.

Other observations from star-catalogues and from periodical publications were occasionally employed, as indicated in the column "Authorities" of the subjoined catalogue. The search for these was greatly facilitated by the use of a manuscript list generously tendered by Mr. C. A. BORST of Johns Hopkins University, and which is an extract from his extensive compilation of star-positions from periodical publications and miscellaneous sources. These positions were used without systematic correction, but were assigned relatively small weights. No elaborate discussion of systematic correction for LAMONT's two catalogues in question was attempted, especially since a new and improved compilation of these observations will soon issue from the Munich observatory. A correction of $-0^s.06$ was applied to the right-ascensions, and specially derived corrections in some instances to the declinations, which appear on the average to be too great. These observations necessarily received small weight in the discussion, but were very useful in many instances in confirming the existence of proper-motion for stars otherwise observed by BESSEL (or another) alone.

The method of combining the various determinations, to ascertain the proper-motion, was briefly as follows. If the star was observed in both coordinates by BRADLEY, the proper-motion is derived from the comparison, Albany—BRADLEY, alone. Otherwise, and for the great majority of telescopic stars, the proper-motion was separately computed from comparison of the Albany position with each of the older authorities, in turn. Virtually, equations of condition containing μ or μ' as the only unknown quantity were thus formed and solved with the use of weights depending upon the supposed precision of the various determinations. The Albany position was thus treated as absolute for its epoch. In only a small proportion of cases would sensibly greater precision have been reached through the more refined process of introducing a correction to the star-position as a second unknown quantity in the equations of condition; while the labor of solution would have been very greatly increased. The proper-motions of fundamental stars are derived by the addition of $+0^s.0005$ to the value of μ, and of $-0''.013$ to the value of μ' contained in AUWERS's *Fundamental Catalog*, except in a few cases where δ and μ' were copied from the Northern Boundary catalogue of 500 stars (*Declination of Fixed Stars*).

It remains to explain the arrangement of the catalogue. The first column contains the current number from the Albany "A.G." catalogue now in press. The magnitudes for the brighter Bradley stars are taken from AUWERS's new catalogue. For the other stars, they are usually the mean between the Albany and *Durchmusterung* estimates, with occasionally greater weight for the former, — fundamental stars excepted, for which positions substantially in conformity with the present system of the *American Ephemeris* are adopted; the basis for the star-positions is the Albany catalogue, which contains from 2 to 7 observations of each star here in question. But to each right-ascension were added, *first*, a systematic correction of $+0^s.008$ to reduce it to NEWCOMB's system; *secondly*, a correction for personal equation dependent on magnitude, amounting to $-0^s.0087\ (M-4.0)$, $-0^s.00116\ (M-4.0)^2$ (See *Astr. Jour.* 195); *thirdly*, a correction for the adopted proper-motion from the mean epoch* of observation to the epoch 1875.0. In an analogous way, the corrections for declination are: *First*, a systematic correction of $+0''.15$, to produce conformity with the system of the *American Ephemeris*; *secondly*, a correction for adopted proper-motion from the epoch of observation to 1875.0. Thus the positions are referred strictly to the equinox of 1875.0, as defined by the system of star-positions in the present *American Ephemeris*. The precessions [and secular variations] are computed with STRUVE's constants. The manner of computing μ and μ' has already been described. When these quantities are deemed to be more accurately determined than in the average of cases, they are given to the fourth and third decimal places respectively. The next two columns give respectively the proper-motion and its direction or position-angle. The abbreviations in the column "Authorities" have already been explained, except as to the numbers following each, and these refer to number of observations. In the last column are references to STRUVE's *Mensurae Micrometricae*, and to notes at the end of the catalogue. Previous computations of proper-motion are also referred to, thus: A = ARGELANDER's researches in Vol. VII of the Bonn observations; A′ = ARGELANDER's later investigations of the proper-motions of telescopic stars, as published in BISCHOF's *Untersuchungen über die Eigenbewegung des Sonnensystems, u.s.w.* (*Inaugural Dissertation*, Bonn 1884); Sj. = SCHJELLERUP, in notes to his catalogue; R = RÜMKER, in notes to his catalogue; G = GRANT, in the introduction to the Glasgow catalogue; D = DREYER, in the *Monthly Notices, R.A.S.*, Vol. XLVI, p. 379; B = BOSSERT, in the introduction, Part I, of the new Paris catalogue. The other references appear to require no special explanation. It should be noted, also, that all stars observed by BRADLEY (of which notice is given in the column of "Authorities") belong to those whose proper-motions may be regarded as well known. Of these there are 53 in the catalogue here presented. These, with 43 additional whose proper-motions have previously been computed by others, make a total of 96, leaving 200 for which the proper-motion is supposed to have been pointed out and computed here for the first time, though it is quite possible that a few of them have been previously made known.

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* The average mean epoch is approximately 1880.5.

CATALOGUE OF STARS HAVING PROPER-MOTION.

Alb. No.	Mag.	α 1875.0	Prec.	Sec. Var.	δ 1875.0	Prec.	Sec. Var.	Proper-Motion				Authorities	Notes
								μ	μ′	Dist.	Pos. Ang.		
	M	h m s	s	s	° ′ ″	″	″	s	″	″	°		
62	9.1	0 15 58.86	+3.0796	+0.0052	+4 32 14.0	+20.006	—0.040	—0.001	—0.15	0.15	183.8	BZ1, Sj3	
91	8.9	24 20.65	3.0821	.0053	3 59 21.5	19.941	.056	—0.002	—0.15	0.15	191.3	BZ1, Sj2, BB1	
128	6.8	31 4.34	3.0800	.0049	2 26 56.6	19.870	.069	+0.0048	—0.077	0.105	136.9	LZ1, Pi, BZ1	
142	7.6	32 41.29	3.0803	.0050	2 26 9.2	19.851	.072	+0.0487	+0.264	0.776	70.1	LZ1, Pi, BZ1, BB7–6	A, B
182	8.1	38 40.36	3.0766	.0046	1 7 14.5	19.769	.084	—0.0040	—0.627	0.630	185.5	LZ1, BZ2, BB5	A, G, B
204	6.3	41 49.62	3.0919	.0066	4 38 15.2	19.721	.090	+0.0539	—1.184	1.433	145.7	LZ1, Pi, R1, Sj1	Maedler
213	8.3	43 58.40	3.0843	.0057	2 42 1.7	19.686	.094	—0.003	—0.10	0.11	201.8	LZ1, BZ1, Lam1	A.N. 668
265	8.2	55 54.13	3.0970	.0072	4 22 48.3	19.461	.117	+0.024	+0.19	0.42	62.8	LZ1, R1, BB3	A′
285	8.7	59 17.46	3.0830	.0060	1 48 23.5	19.387	.123	—0.012	+0.02	0.18	276.3	LZ1, BZ1	
286	6.4	59 21.24	3.0977	.0073	4 14 31.4	19.386	.124	—0.001	—0.133	0.133	180.4	Br4–3	} 290
287	7.3	0 59 23.43	+3.0977	+0.0073	+4 14 35.7	+19.385	—0.124	—0.0011	—0.113	0,114	188.1	Br *a*2, D′A1, LZ1, Pi	

Alb. No.	Mag.	α 1875.0	Prec.	Sec. Var.	δ 1875.0	Prec.	Sec. Var.	Proper Motion.				Authorities	Notes
								μ	μ'	Dist.	Pos. Ang.		
	M	h m s	s	s	° ' "	"	"	s	"	"	°		
303	6.6	1 1 33.03	+3.0805	+0.0059	+1 20 21.0	+19.335	—0.128	+0.0089	—0.449	0.461	163.5	Br6-2	
305	5.6	1 55 92	3.1034	.0078	4 59 16.5	19.327	.129	—0.0180	—0.187	0.328	235.3	Br8-4	
322	8.6	5 27.08	3.1000	.0075	4 13 5.0	19.242	.136	—0.015	—0.18	0.28	230.8	R1, Sj1	
325	6.5	6 6.06	3.0843	.0064	1 48 38.3	19.226	.136	—0.0125	—0.118	0.222	237.9	Br α2, LZ3, Pi, BZ1, Sj1	Sj
357	8.7	12 13.79	3.0972	.0075	3 26 56.1	19.066	.148	—0.008	—0.01	0.12	265.2	BZ2	
362	7.6	12 56.10	3.0915	.0071	2 37 56.1	19.047	.149	+0.0077	—0.020	0.117	99.9	Pi, BZ1, Sj1	
369	8.6	15 51.10	3.0940	.0073	2 51 48.8	18.966	.155	+0.001	—0.13	0.13	171.3	BZ1, R1	
404	7.5	21 10.54	3.1104	.0085	4 42 27.9	18.809	.165	—0.0025	—0.158	0.162	193.2	Br4-3	Note 1
439	8.4	27 41.09	3.0880	.0073	1 48 28.2	18.604	.176	+0.002	—0.17	0.17	170.0	BZ1, R1	Note 2
459	8.9	32 22.55	3.1135	.0088	4 29 44.7	18.447	.186	+0.008	+0.08	0.15	58.4	BZ1, R3	
472	8.2	34 39.33	3.1011	.0082	3 4 34.9	18.368	.189	—0.010	+0.09	0.18	301.0	LZ1, BZ2	
504	8.9	40 11.23	3.1111	.0088	3 55 21.8	18.168	.200	+0.008	—0.15			BZ1, Sj1	Note 3
547	6.1	49 26 18	3.0854	.0078	1 13 45.9	17.811	.211	+0.0088	+0.154	0.203	40.6	LZ1, Pi, BZ1, Str5, Sj1	Σ186
560	6.3	53 39.10	3.1000	.0085	2 29 54.8	17.638	.223	+0.0150	—0.256	0.341	138.2	Br17-6	
631	8.5	2 8 38.01	3.1129	.0092	3 16 11.9	16.977	.249	—0.004	—0.09	0.10	209.1	LZ2, BZ2, Sj1	
648	5.9	11 31.87	3.0870	.0083	1 9 56.3	16.841	.252	+0.0205	+0.348	0.469	41.4	LZ2, Pi, BZ2, R1, Sj3, BB6	A.B
676	8.1	19 25.15	3.1419	.0103	5 12 35.5	16.457	.269	+0.0275	+0.061	0.415	81.5	LZ1, BZ1, Wien2, Par3-1	Note 4 B
720	8.1	28 37.77	3.1228	.0097	3 34 42.7	15.983	.282	+0.014	+0.10	0.23	64.5	BZ2	
759	3.3	36 49.51	3.1122	.0094	2 42 28.2	15.540	.294	—0.0109	—0.158	0.227	225.9	Fund. Catalogue	Σ299
786	8.6	43 12 67	3.0919	.0088	1 17 30.1	15.180	.301	+0.013	—0.10	0.21	117.8	BZ1, R1	
792	8.5	44 40.20	3.1326	.0099	3 55 25.7	15.096	.307	+0.009	—0.03	0.13	103.0	LZ1, BZ2	
811	7.0	47 11.01	3.0950	.0089	1 27 42.9	14.951	.307	—0.005	—0.19	0.20	200.2	LZ2, BZ1, Sj1	G.B
840	7.7	50 46.67	3.0942	.0089	1 23 9.1	14.739	.312	+0.006	—0.09	0.13	135.0	LZ1, Par2, Sj4	
843	9.0	51 41.26	3.1252	.0097	3 19 38.5	14.685	.317	+0.003	—0.14	0.15	160.3	BZ1, R2	
851	8.2	54 21.74	3.1496	.0104	4 47 38.4	14.525	.323	+0.008	—0.15	0.19	141.3	BZ1, BB1	
957	5.0	3 12 48.38	3.1228	.0094	2 54 37.4	13.366	.345	+0.0173	+0.089	0.274	71.0	Br5-5	
1186	5.8	57 37.78	3.1222	.0083	2 29 8.5	10.206	.396	+0.0090	—0.127	0.185	133.2	LZ1, Pi, BZ1	G.B
1210	7.0	4 3 11.17	3.1333	.0082	2 59 38.3	9.785	.403	—0.0054	—0.067	0.105	230.4	LZ3, BZ2, BB4, Sj1	
1215	6.0	4 41.08	3.1787	.0087	5 11 15.3	9.670	.410	+0.0091	+0.001	0.136	89.6	Br5-8	
1221	8.9	5 31.81	3.1724	.0086	4 52 33.4	9.605	.410	—0.003	—0.13	0.14	201.0	BZ2	
1234	8.9	7 57.85	3.1278	.0080	2 41 40.2	9.418	.407	+0.011	+0.28	0.33	31.3	BZ2	
1252	8.5	10 17.95	3.1600	.0083	4 13 50.8	9.237	.413	+0.013	—0.02	0.20	95.7	LZ2, BZ1	
1283	7.3	15 16.06	3.1162	.0075	2 5 47.8	8.849	.412	—0.001	—0.14	0.14	184.5	LZ1, BZ1, BB2, Sj1	G.B
1342	8.5	30 9.08	3.1427	.0071	3 15 55.1	7.662	.427	+0.009	—0.23	0.26	150.5	BZ2, Sj1	Note 5
1391	8.5	38 10.54	3.1831	.0071	5 3 28.8	7.009	.438	—0.010	—0.06	0.16	248.2	LZ1, BZ2	} Σ589
1392	8.5	38 10.76	3.1831	.0071	5 3 25.7	7.008	.438	—0.0075	—0.060	0.128	242.0	BZ2, Str6	
1420	7.0	41 56.36	3.1270	.0064	2 29 21.9	6.699	.433	—0.002	+0.10	0.10	343.3	LZ1, BZ1	
1453	8.1	45 44.34	3.1010	.0060	1 17 53.7	6.385	.431	—0.005	—0.13	0.15	211.6	LZ1, BZ1, BB1	B
1455	8.7	45 47.69	3.1636	.0065	4 7 20.3	6.380	.441	+0.008	0.00	0.12	90.0	LZ1, BZ1	B
1480	7.5	49 17.80	3.1719	.0064	4 28 31.0	6.089	.443	+0.010	—0.34	0.37	156.2	LZ1, BZ1, Sj1	
1559	8.3	57 55.66	3.0930	.0054	0 55 21.6	5.365	.437	—0.001	—0.11	0.11	185.2	BZ2, Sj1	
1600	7.6	5 5 8.47	3.1688	.0054	4 15 10.3	4.754	.451	+0.013	—0.11	0.23	118.8	BZ2	
1618	8.6	11 54.50	3.1840	.0051	4 53 10.1	4.178	.456	+0.011	—0.11	0.20	122.9	BZ2	
1659	7.8	13 17.66	3.1268	.0047	2 23 8.0	4.059	.448	+0.0012	—0.115	0.116	171.1	LZ1, Pi, BZ1	
1880	6.2	40 8.14	3.0983	.0031	1 7 20.7	1.736	.451	—0.0041	—0.139	0.154	205.4	LZ2, Pi, BZ2, Sj1	B
1933	8.5	46 21.91	3.1426	.0027	3 1 10.5	1.188	.458	+0.001	—0.12	0.12	175.2	LZ1, BZ1	
1976	8.2	53 36.08	3.1850	.0023	4 49 16.4	0.560	.465	—0.006	+0.12	0.15	323.1	LZ1, BZ1, Sj1	
1979	8.5	53 51.56	3.1139	.0023	1 47 3.2	+0.537	.451	—0.008	—0.10	0.15	227.7	LZ1, BZ2	B
2049	7.4	6 3 16 58	3.1398	.0017	2 53 29.6	—0.287	.458	—0.008	—0.09	0.15	233.1	LZ1, BZ1, BB1	
2073	8.1	7 19.81	3.1388	.0014	2 51 0.5	0.641	.457	+0.002	—0.24	0.24	172.9	LZ1, Sj2	
2103	6.6	10 38.79	3.1923	.0011	5 8 12.4	0.931	.465	—0.0167	+0.146	0.290	300.3	LZ1, Pi, BZ1, Sj1	Sj.A
2221	8.3	24 21.31	3.1791	+0.0002	4 35 42.2	2.132	.460	+0.004	—0.09	0.11	142.1	LZ1, BZ1	
2502	8.5	49 28.99	3.1297	—0.0011	2 31 2.8	4.297	.441	+0.009	—0.05	0.14	111.0	LZ1, BZ1	
2511	7.9	50 6.51	3.1028	.0010	1 20 33.0	4.350	.440	+0.001	—0.57	0.57	179.0	BZ1, Alb. '87 2	Note 6
2665	8.6	7 3 57.15	3.1136	.0018	1 50 15.6	5.524	.434	—0.002	—0.12	0.12	194.0	LZ1, BZ1	
2694	6.2	7 47.08	3.1565	.0023	3 19 25.8	5.845	.436	—0.0092	+0.02	0.14	278.1	LZ1, Pi, BZ1	
2716	8.0	10 6.31	3.1190	.0022	2 6 6.0	6.039	.431	+0.0035	—0.134	0.144	158.8	LZ2, BZ1, BB3	
2819	7.9	7 19 8.87	+3.1755	—0.0032	+4 41 38.5	—6.789	—0.433	—0.002	—0.10	0.10	196.7	LZ1, BZ1	

Alb. No.	Mag.	α 1875.0	Prec.	Sec. Var.	δ 1875.0	Prec.	Sec. Var.	Proper-Motion				Authorities	Notes
								μ	μ'	Dist.	Pos. Ang.		
	M	h m s	s	s	° ′ ″	″	″	s	″	″	°		
2958	6.8	7 34 13.85	+3.1657	—0.0039	+4 21 41.7	— 8.015	—0.420	—0.0031	—0.094	0.105	206.0	LZ1, Pi, BZ1	Note 7
2960	8.6	34 31.72	3.0918	.0031	0 54 53.9	8.039	.410	—0.001	—0.15	0.15	183.8	BZ1, Lam2	
2985	7.6	36 57.23	3.1529	.0039	3 47 1.5	8.233	.416	+0.0024	—0.090	0.097	158.2	LZ1, Str3	Σ1134
3108	6.7	50 50.11	3.1024	.0038	1 27 33.1	9.325	.397	—0.012	0.00	0.18	270.0	LZ1, BZ1, Lam2	
3112	6.0	51 51.77	3.1250	.0012	2 33 23.3	9.404	.398	—0.0116	+0.087	0.195	296.6	Br8–5	
3143	5.0	55 15.78	3.1269	.0043	2 40 35.0	9.704	.395	—0.0015	+0.110	0.112	348.7	Br7–3	
3144	8.2	55 50.51	3.1613	.0049	4 30 5.7	9.711	.400	+0.0062	—0.098	0.135	223.5	LZ1, BZ1, Str4	Σ1175
3305	8.5	8 12 52.58	3.1063	.0046	1 43 48.3	10.987	.374	—0.013	—0.06	0.20	252.5	BZ1, Lam2	
3327	7.6	14 48.79	3.1007	.0045	1 27 48.5	11.128	.371	+0.004	—0.12	0.13	153.4	LZ1, BZ1, Lam3	
3378	7.9	21 4.25	3.0958	.0046	1 14 13.5	11.579	.364	+0.010	+0.03	0.15	78.7	LZ1. BZ1, Lam2	
3384	8.7	21 44.31	3.0972	.0047	1 18 46.5	11.627	.363	—0.001	—0.11	0.11	190.3	LZ1, BZ1, Lam3	
3391	8.5	22 57.12	3.1646	.0059	4 52 2.8	11.713	.370	—0.002	—0.19	0.19	189.0	BZ2	
3493	7.9	35 50.00	3.1637	.0062	5 1 18.8	12.609	.353	+0.004	—0.21	0.22	164.0	LZ1, BZ2	
3506	8.5	37 29.15	3.1643	.0063	5 5 31.9	12.721	.351	—0.011	—0.04	0.16	256.0	LZ1, BZ1	
3552	7.6	43 24.63	3.1222	.0055	2 49 42.9	13.118	.339	+0.001	—0.10	0.10	174.3	LZ1. BZ1, Lam1	G
3611	8.6	50 54.88	3.1567	.0065	4 54 55.0	13.607	.332	—0.006	—0.14	0.17	212.7	LZ1, BZ1, BB1	
3651	8.7	57 42.65	3.1312	.0060	3 31 51.8	14.038	.320	+0.004	—0.10	0.12	149.0	BZ2,Lam1	
3652	8.4	57 43.80	3.1310	.0060	3 31 25.3	14.039	.320	+0.005	—0.13	0.15	151.7	BZ1, Lam1, Sj1	
3711	4.0	9 7 51.61	3.1175	.0057	2 50 25.5	14.659	.304	+0.0083	—0.322	0.345	158.9	Fund. Catalogue	
3735	8.3	13 3.14	3.0944	.0051	1 25 37.8	14.965	.294	—0.008	—0.16	0.20	216.9	BZ1, Lam4, Sj1	
3790	8.6	21 26.21	3.1227	.0059	3 23 0.7	15.443	.284	+0.003	+0.13	0.14	21.0	LZ1, BZ1	
3812	8.6	28 2.25	3.1314	.0062	4 6 33.0	15.805	.274	+0 003	+0.11	0.12	24.4	LZ1, BZ1, Lam2	
3819	8.1	28 54.17	3.1362	.0063	4 27 51.3	15.851	.273	—0.0042	—0.092	0.111	214.4	LZ1, BZ1. Str5	Σ1371
3831	7.3	31 13.93	3.1041	.0053	2 15 19.2	15.975	.267	—0.0079	+0.024	0.120	281.5	LZ2, Pi. BZ1, Lam2	
3832	8.1	31 50.69	3.1060	.0054	2 23 54.3	16.008	.266	—0.0139	—0.045	0.213	257.8	LZ2, Pi. BZ1, Sj1	
3870	8.0	40 6.26	3.1029	.0052	2 17 41.3	16.433	.252	—0.0092	+0.004	0.138	271.6	LZ2, Pi, BZ1	
3882	6.5	43 59.82	3.1367	.0064	4 55 40.1	16.625	.248	—0.0087	—0.052	0.140	248.2	Br1–3	
3892	8.7	45 45.23	3.1214	.0058	3 48 23.5	16.711	.244	—0.027	—0.01	0.41	268.6	BZ1, Lam1	
3893	6.0	45 45.25	3.1114	.0055	3 2 10.1	16.711	.244	—0.0128	+0.108	0.220	299.4	Br3–3	
3906	9.1	49 16.63	3.0947	.0048	1 46 47.9	16.880	.236	+0.005	—0.22	0.234	160.0	BZ1. Lam2	
3911	7.1	50 19.04	3.1329	.0062	4 50 11.3	16.928	.238	—0.0134	—0.065	0.211	252.1	LZ1. BZ2, BB2	
3936	8.3	55 44.50	3.1270	.0060	4 32 2.9	17.178	.228	+0.0005	—0.100	0.100	176.0	LZ2, BZ2, Lam1, Leid2	
3948	6.4	57 39.85	3.1175	.0056	3 48 30.8	17.264	.224	—0.0051	—0.105	0.130	215.9	Br22–6	
3956	8.1	10 0 1.63	3.1200	.0057	4 5 4.4	17.369	.220	—0.0076	—0.084	0.142	233.7	LZ1, Pi, BZ1, BB1	
3969	7.6	2 57.30	3.1063	.0050	2 59 0.7	17.495	.214	—0.015	—0.03	0.23	262.6	LZ1, BZ1, Lam1	G
3990	7.9	7 37.66	3.1139	.0053	3 47 2.2	17.692	.206	+0.0139	—0.421	0.470	206.3	LZ1, BZ1, BB3, Sj1	A'G
4025	7.8	17 16.60	3.1052	.0048	3 15 35.0	18.073	.188	—0.010	—0.25	0.29	211.0	LZ1, BZ1	G
4045	7.3	21 2.57	3.1133	.0051	4 12 2.2	18.214	.182	—0 0094	—0.028	0.144	258.8	D'A2,LZ2,BZ1,Lam2	
4057	7.2	23 17.24	3.0926	.0040	2 8 3.6	18.295	.177	—0.011	—0.19	0.25	220.8	LZ1, BZ1, Lam5, Sj1	
4076	7.8	28 7.28	3.0942	.0040	2 24 31.4	18.464	.168	—0.011	—0.12	0.20	233.1	LZ1, BZ1, Lam5	G
4103	6.7	36 10.17	3.1077	.0046	4 14 8.7	18.728	.154	—0.0079	+0.022	0.120	280.6	Br6–3	
4147	7.8	44 46.12	3.0977	.0038	3 22 25.6	18.983	.137	—0.008	—0.12	0.170	225.0	LZ1. BZ1, Lam2, Sj1	
4201	5.8	11 0 31.65	3.0880	.0027	2 38 1.2	19.383	.107	—0.0274	—0.078	0.418	259.3	Br5–4	
4209	8.0	3 16.52	3.0902	.0028	3 7 55.7	19.443	.102	—0.021	+0.01	0.31	271.9	LZ1, BZ1, Lam1, Sj1	D
4229	8.4	8 52.09	3.0864	.0023	2 44 54.4	19.557	.091	—0.002	—0.12	0.12	194.0	LZ1, BZ2, Lam4, BB1	
4232	8.8	9 26.89	3.0864	.0023	2 46 5.8	19.568	.090	+0.012	—0.03	0.18	99.5	BZ2, Lam2	
4235	5.8	10 51.45	3.0856	.0022	2 41 51.4	19.595	.087	+0.0018	—0.155	0.157	171.2	Br7–3	
4256	8.9	15 44.77	3.0758	.0010	0 48 49.5	19.682	.078	—0.002	—0.13	0.13	193.0	LZ1, BZ1, Sj1	
4262	8.7	17 26.62	3.0908	.0027	4 18 31.0	19.709	.075	—0.008	—0.10	0.16	230.2	LZ1. Lam3, Camb2–3	
4272	6.7	19 24.62	3.0910	.0027	4 32 55.3	19.741	.071	—0.0059	—0.037	0.095	247.2	Br9–3	
4278	6.7	20 25.68	3.0871	.0022	3 41 39.6	19.756	.069	—0.0506	+0.170	0.776	282.7	Br6–3	Σ1540
4279	8.1	20 26.69	3.0870	.0022	3 41 13.7	19.756	.069	—0.0495	+0.143	0.755	280.9	LZ2, Pi, BZ1, R2	
4280	7.6	20 57.49	3.0804	.0013	2 3 54.1	19.764	.068	0.000	—0.14	0.14	180.0	LZ1, BZ1, Lam4	
4282	7.8	21 9.25	3.0787	.0011	1 38 48.6	19.767	.067	—0.003	—0.15	0.16	198.4	LZ1, BZ1, Camb1. Lam3	
4286	8.0	22 0.49	3.0856	.0020	3 28 25.2	19.779	.066	—0.0090	—0.050	0.144	249.7	LZ1, Pi, BZ1, Poulk2	
4307	6.0	27 58.09	3.0845	.0019	3 45 15.7	19.859	.054	—0.0124	—0.107	0.215	240.1	Br7–4	
4309	8.9	29 23.16	3.0750	.0003	0 54 3.5	19.876	.051	—0.013	—0.10	0.21	242.2	BZ1, Lam2	
4325	8.5	33 5.18	3.0819	.0015	3 32 7.9	19.916	.044	—0.014	+0.08	0.225	290.9	LZ1, BZ1, Lam2, Sj1	
4347	8.5	11 39 6.35	+3.0794	—0.0010	+3 20 41.4	—19.971	—0.032	—0.010	—0.15	0.21	225.0	LZ1, BZ1, Lam1	

Alb. No.	Mag.	α 1875.0	Prec.	Sec. Var.	δ 1875.0	Prec.	Sec. Var.	Proper Motion μ	Proper Motion μ	Dist.	Pos. Ang.	Authorities	Notes
	M	h m s	s	s	° ′ ″	″	″	s	″	″			
4348	8.3	11 39 18.99	+3.0796	−0.0011	+3 31 9.8	−19.973	−0.032	−0.010	−0.13	0.20	229.1	LZ1, BZ1, Lam2	
4361	3.3	44 11.03	3.0762	.0003	2 28 8.4	20.007	.022	+0.0486	−0.282	0.781	111.2	Fund. Catalogue	
4362	8.8	45 13.31	3.0782	−0.0010	3 57 21.8	20.013	.020	−0.010	−0.03	0.15	258.7	LZ1, BZ1, Lam2	
4374	7.9	49 0.04	3.0743	+0.0003	1 47 34.3	20.031	−0.013	−0.005	−0.07	0.10	225.0	D'A2, LZ1, BZ1, Lam2	
4408	8.7	57 33.81	3.0732	−0.0004	1 3 13.9	20.053	+0.004	−0.010	+0.05	0.16	288.4	LZ1.BZ1.BB8-7.Sj1	A
4409	8.8	57 40.94	3.0732	−0.0003	4 3 24.3	20.053	.004	+0.0015	−0.480	0.480	177.4	LZ1, BZ1, BB8	Sj, A
4419	8.1	58 47.07	3.0726	+0.0003	2 52 53.1	20.051	.006	−0.004	−0.11	0.13	208.6	BZ2, R2, Lam3	
4440	6.5	12 3 16.99	3.0714	.0007	2 35 59.9	20.052	.015	+0.0016	−0.191	0.195	173.0	Br8-4	
4465	5.0	14 0.09	3.0665	.0006	4 0 32.3	20.017	.036	−0.0206	−0.078	0.318	255.8	Br4-5	
4467	8.8	15 2.71	3.0670	.0010	3 25 23.0	20.011	.038	−0.017	−0.04	0.25	260.9	LZ1, BZ1, Lam3, Camb1	
4472	8.5	17 6.16	3.0698	.0021	1 21 44.4	19.998	.042	0.000	−0.20	0.20	180.0	BZ1, Lam2	
4496	8.6	22 31.38	3.0680	.0022	1 50 37.6	19.957	.053	−0.004	−0.12	0.13	206.5	LZ1, BZ1, Camb1-2, Lam2	
4511	8.3	26 45.56	3.0675	.0025	1 44 9.7	19.918	.061	−0.006	−0.09	0.13	225.0	LZ1, BZ1 Sj1	
4518	7.3	28 53.80	3.0636	.0020	2 56 54.3	19.895	.065	−0.0068	+0.044	0.111	293.3	LZ1.BZ1.R2.Lam1.Camb1	
4578	8.4	43 22.20	3.0639	.0033	1 53 31.3	19.696	.093	−0.002	−0.71	0.71	182.4	LZ1, Lam1, Sj1	A
4580	8.4	44 28.69	3.0533	.0022	1 11 53.9	19.678	.094	+0.006	−0.11	0.11	140.2	LZ1, BZ1, Sj2	
4608	3.0	49 18.14	3.0519	.0026	4 4 37.9	19.592	.104	−0.0331	−0.060	0.499	263.1	Fund. Catalogue	
4624	9.4	54 55.21	3.0465	.0026	4 38 29.7	19.481	.114	−0.012	−0.07	0.19	248.7	BZ1, Lam1	
4638	7.6	58 21.52	3.0665	.0046	0 58 11.3	19.408	.121	−0.0019	−0.105	0.109	194.9	LZ1, Pi, BZ1, Sj2 Sj1	
4641	8.0	59 24.07	3.0437	.0028	4 45 49.9	19.384	.122	+0.0041	−0.091	0.110	145.9	LZ1, Pi, BZ3, Lam3, BB1.	
4644	7.9	13 0 57.11	3.0645	.0046	1 15 26.8	19.319	.126	−0.0064	−0.138	0.168	214.8	BZ1, Str4, Sj1	Note 8
4660	8.4	4 29.58	3.0567	.0042	2 23 39.2	19.265	.132	+0.003	−0.11	0.12	155.6	LZ2, BZ1, Lam1	
4671	8.8	9 4.68	3.0453	.0037	3 53 5.1	19.150	.140	−0.010	−0.06	0.16	248.2	LZ2, BZ1	
4699	8.6	14 28.18	3.0365	.0035	4 46 56.9	19.005	.150	−0.035	+0.21	0.57	291.8	BZ2, Lam2	
4708	7.3	17 17.95	3.0462	.0043	3 22 12.1	18.924	.155	−0.0001	+0.202	0.202	359.5	D'A1, LZ1, BZ1, Str5	G } Σ1740
4709	7.9	17 19.67	3.0462	.0043	3 22 18.2	18.923	.155	0.000	+0.23	0.23	0.0	LZ1, BZ1	G }
4723	9.3	21 19.92	3.0424	.0044	3 40 24.8	18.805	.162	−0.011	−0.03	0.17	260.0	BZ1, Lam1	
4734	7.3	23 24.99	3.0577	.0054	1 41 44.8	18.740	.167	−0.0067	−0.168	0.196	211.0	LZ1, Lam1, BB7	
4744	8.4	25 36.06	3.0308	.0040	4 51 26.4	18.672	.169	−0.0069	+0.033	0.108	287.8	LZ1, BZ3, Lam2	
4772	8.3	34 5.28	3.0462	.0054	2 47 35.4	18.388	.185	+0.004	−0.13	0.14	155.2	D'A a1, LZ1, BZ1, Lam2	Note 9 A
4781	5.8	36 46.81	3.0323	.0048	1 10 16.5	18.293	.189	−0.0207	−0.077	0.319	256.1	Br7-3	Σ1777
4820	9.1	48 59.34	3.0525	.0063	1 50 57.7	17.829	.211	−0.010	−0.14	0.21	227.0	BZ1, Lam1	
4855	7.5	56 30.63	3.0250	.0056	4 9 7.9	17.518	.222	−0.0145	−0.091	0.235	247.2	LZ1, Pi, BZ1	
4867	8.6	58 39.60	3.0428	.0061	2 32 59.5	17.426	.227	−0.013	+0.02	0.19	276.0	BZ2, Lam1	
4891	8.7	14 4 39.92	3.0118	.0055	4 59 41.3	17.160	.235	−0.0104	+0.021	0.157	277.7	LZ1, Pi, BZ2, Lam2	
4915	7.6-7.9	9 2.34	3.0259	.0062	3 42 46.7	16.959	.243	−0.0122	+0.023	0.181	277.2	LZ1, BZ1, Str1	Note 10
4941	6.4	16 51.87	3.0483	.0072	1 49 11.7	16.583	.257	+0.010	−0.49	0.51	163.0	LZ1, BZ1, Lam3	G
5011	8.8	31 29.73	3.0166	.0067	3 52 38.9	15.830	.277	−0.019	+0.04	0.29	277.9	BZ1, Lam1	
5043	8.8	39 0.52	2.9966	.0064	5 3 27.5	15.118	.286	−0.007	+0.10	0.15	312.3	LZ1, BZ1, Sj1	
5046	3.6	39 55.82	3.0359	.0071	2 25 14.9	15.366	.292	−0.0089	−0.040	0.139	253.3	Fund. Catalogue	
5054	8.1	41 0.07	3.0235	.0071	3 13 51.5	15.306	.291	−0.026	−0.07	0.40	259.8	BZ1, Lam1	
5111	7.1	54 44.43	3.0174	.0072	3 23 49.3	14.502	.310	−0.006	−0.09	0.13	225.0	LZ1.BZ1, R1, Sj1	
5114	8.5	55 36.25	3.0098	.0070	3 51 19.3	14.450	.311	−0.014	+0.07	0.22	288.4	LZ1, BZ1, Lam1	Note 11
5117	9.0	56 32.77	3.0380	.0076	2 6 28.7	14.392	.315	−0.002	+0.13	0.13	317.0	R2, BB1-2	
5159	8.3	15 5 57.72	2.9909	.0068	4 47 42.4	13.807	.322	−0.0081	−0.024	0.123	258.8	LZ1, BZ3, Lam3, Sj1	
5174	5.8	9 27.16	3.0579	.0081	0 50 10.3	13.584	.331	−0.0074	−0.005	0.111	267.4	Br2-3	
5176	7.4	9 35.81	3.0505	.0079	1 15 54.4	13.574	.333	+0.009	−0.11	0.18	231.8	LZ1, BZ1, R1	
5186	5.0	12 55.96	3.0333	.0076	2 14 22.8	13.358	.336	+0.0231	−0.542	0.615	212.9	Br2-3	Σ19..
5190	6.0	14 40.28	3.0517	.0080	1 10 17.3	13.244	.340	−0.0043	−0.107	0.125	210.9	Br5-[illegible]	
5192	8.5	16 25.13	3.0391	.0077	1 52 16.8	13.129	.341	−0.0262	−0.257	0.531	227.7	BZ1, R3, Lam1	
5216	6.0	22 19.47	3.0312	.0076	2 16 40.4	12.734	.347	−0.0059	0.052	0.102	229.4	Br2-[illegible]	
5230	7.6	25 21.37	3.0483	.0078	1 18 50.0	12.528	.353	−0.0042	−0.108	0.125	210.3	LZ1, BZ2, Lam1, Sj1	
5269	6.1	37 11.66	3.0168	.0072	2 55 2.8	11.664	.363	−0.0058	−0.156	0.179	209.1	Br4-1	
5271	8.5	39 2.93	2.9747	.0066	5 6 21.6	11.571	.359	−0.003	−0.16	0.16	191.0	BZ1, Lam1	
5289	8.0	44 51.02	3.0345	.0074	1 57 51.1	11.369	.369	−0.006	−0.22	0.21	202.2	BZ1, Lam1, Sj1	
5301	3.3	44 35.15	2.9779	.0066	4 51 19.6	11.172	.366	+0.0078	+0.068	0.129	58.[illegible]	Fund. Catalogue	
5375	8.7	16 4 50.71	3.0059	.0066	3 11 31.9	9.658	.388	+0.0001	−0.106	0.106	179.5	LZ1, BZ1, R6, BB2	
5419	8.5	16 15 27.75	+3.0511	+0.0068	+0 52 0.1	−8.833	+0.404	+0.005	−0.21	0.22	191.6	LZ1, BZ1, Lam7	A

Alb. No.	Mag.	α 1875.0	Prec.	Sec. Var.	δ 1875.0	Prec.	Sec.Var.	Proper-Motion. μ	Proper-Motion. μ′	Proper-Motion. Dist.	Proper-Motion. Pos. Ang.	Authorities	Notes
	M	h m s	s	s	° ′ ″	″	″	s	″	″	°		
5120	5.0	16 15 14.56	+3.0145	+0.0067	+1 19 27.9	— 8.812	+0.403	—0.0124	+0.026	0.188	278.0	Br11-3	
5434	8.7	17 4.93	3.0335	.0066	1 50 38.6	8.706	.402	—0.002	—0.17	0.17	190.0	BZ1, Lam3, BB1, Sj1	
5459	8.9	22 20.94	2.9967	.0061	3 33 1.1	8.288	.402	—0.001	—0.51	0.51	181.1	BZ2. R2	
5471	7.6	24 19.63	2.9761	.0059	4 30 0.5	8.131	.400	—0.0333	—1.391	1.478	199.8	LZ2, BZ2, R5, BB10	A,G
5473	3.7	24 36.60	3.0210	.0063	2 15 32.6	8.106	.407	—0.0022	—0.098	0.103	198.6	Fund. Catalogue	Σ2055
5479	8.4	26 32.96	3.0218	.0062	2 21 17.6	7.952	.408	—0.0021	—0.106	0.111	196.8	LZ1, Pi, Lam1, Sj1	
5480	8.9	26 39.65	2.9967	.0060	3 31 10.0	7.944	.405	—0.0206	—0.182	0.359	239.5	BZ2, R2, Lam1	
5496	8.1	29 44.19	3.0368	.0062	1 38 34.2	7.696	.412	—0.0101	—0.082	0.172	241.4	D'A1, LZ1, Lam9, Sj2	
5521	9.2	35 9.97	3.0383	.0060	1 33 39.9	7.255	.416	—0.007	—0.15	0.19	216.3	BZ1, Lam2	
5524	6.0	35 22.67	3.0413	.0060	1 25 18.0	7.238	.417	—0.0087	+0.026	0.133	281.3	Br6-1	
5548	8.9	40 8.64	2.9598	.0053	5 6 55.0	6.847	.409	—0.014	—0.02	0.21	261.5	LZ1, BZ1, Lam1 [Sj2	
5551	7.2	40 35.68	3.0180	.0057	2 28 7.4	6.810	.417	—0.0075	+0.031	0.116	285.5	Br α1.LZ1,Gch12yr1-6,	Note 12
5571	8.6	44 53.27	2.9615	.0051	5 0 3.2	6.455	.412	+0.004	—0.14	0.15	156.8	BZ2, Lam2, Sj1	
5592	9.0	50 54.67	2.9973	.0051	3 21 33.9	5.954	.420	0.000	—0.22	0.22	180.0	BZ2, Lam1	Note 13
5634	6.2	58 55.02	3.0523	.0051	0 53 18.1	5.282	.432	—0.001	—0.38	0.38	183.0	LZ1, BZ3, Lam10, Sj1	A′
5662	9.1	17 1 52.67	3.0295	.0048	1 53 24.8	5.031	.430	—0.007	—0.21	0.23	205.5	BZ1, Lam4	9^{M}.8, 3″.5, 230
5663	7.4	2 10.48	2.9681	.0045	4 35 46.7	5.006	.421	—0.0036	—0.207	0.214	194.6	LZ1, BZ2, R1	
5738	7.0	14 48.52	3.0365	.0043	1 33.38.6	3.929	.436	—0.009	+0.24	0.28	329.7	LZ1, BZ1, Lam7	A′,G
5752	9.2	16 3.38	3.0158	.0041	2 27 51.8	3.822	.433	—0.010	—0.21	0.26	215.5	R2. Lam2	
5759	8.8	17 39.56	2.9581	.0039	4 57 47.4	3.684	.426	—0.010	—0.19	0.24	218.3	BZ1, Lam2, Sj1 [Sj1.BB4	
5766	8.0	19 32.21	3.0202	.0040	2 15 54.8	3.523	.435	—0.0399	—1.169	1.313	207.1	BZ1,Sant3,R1,Lam6,	R,Sj,A,G
5786	8.9	22 23.25	3.0066	.0038	2 51 4.0	3.276	.434	—0.005	—0.26	0.27	195.1	R1, Lam3	Note 14
5800	9.0	24 25.29	3.0163	.0037	2 25 29.9	3.101	.436	+0.003	—0.13	0.14	159.0	BZ1, R5	
5866	6.6	33 4.60	2.9880	.0032	3 37 51.3	2.350	.434	—0.0123	—0.121	0.220	236.6	LZ1, Pi, R1, Lam2	A′
5892	3.0	37 17.88	2.9647	.0030	4 37 16.5	1.983	.431	—0.0036	+0.154	0.163	340.7	Fund. Catalogue	
5952	8.8	44 10.26	2.9764	.0027	4 6 41.0	1.384	.434	—0.009	—0.10	0.16	232.4	LZ1, BZ1, Lam1	Note 15
5957	9.8	45 15.98	3.0247	.0027	2 2 33.5	1.288	.441	+0.012	+0.06	0.19	71.6	R1, Lam1	Note 16
6001	8.8	51 10.10	2.9576	.0024	4 54 19.1	0.772	.431	+0.005	—0.12	0.14	149.7	LZ1, BZ1	
6060	8.4	57 42.21	3.0295	.0020	1 49 50.9	0.201	.442	+0.005	—0.08	0.011	138.8	LZ1, BZ1, Sj1	
6073	4.3	59 8.34	3.0132	+0.0020	2 31 49.6	0.075	.439	+0.0143	—1.127	1.147	169.3	Br18-5	Σ2272
6076	7.0	59 27.09	2.9633	—0.0020	4 39 37.3	— 0.048	.432	—0.001	—0.30	0.30	183.8	BZ1, Lam4, Sj1	
6121	6.2	18 3 38.78	2.9997	+0.0017	3 6 21.5	+ 0.319	.437	+0.003	—0.19	0.20	165.3	D'A1, BZ1, Kg2 [Sj1	
6273	8.5	28 16.03	3.0262	.0005	1 59 8.1	2.467	.437	+0.004	—0.13	0.14	155.2	LZ1, BZ1, Lam5, BB1,	
6275	8.2	28 47.26	2.9762	+0.0006	4 8 34.4	2.512	.430	—0.006	—0.12	0.15	216.9	BZ1, Lam10.9	Note 17
6395	7.7	45 32.70	3.0061	—0.0003	2 53 20.9	3.959	.428	—0.001	—0.12	0.12	189.4	LZ2, Lam2. Sj3	
6423	8.2	49 28.59	2.9784	.0003	4 6 36.7	4.296	.422	—0.002	—0.16	0.16	190.6	LZ1, Lam2	
6433	7.2	50 24.89	2.9786	.0004	4 6 26.1	4.376	.422	—0.0009	—0.106	0.107	187.0	LZ1, Pi, BZ1, Lam11	Note 18
6474	7.1	54 53.94	3.0197	.0008	2 18 57.4	4.758	.426	—0.001	—0.32	0.32	183.5	Lam5, BB1, Sj1	
6557	8.7	19 3 21.28	3.0489	.0014	1 2 25.8	5.473	.425	0.000	—0.17	0.17	180.0	BZ4, Lam14	
6635	7.1	14 8.41	2.9713	.0013	4 33 5.0	6.375	.408	—0.0021	—0.117	0.121	194.8	LZ1, Pi, Lam4, Sj2	
6669	3.3	19 11.76	3.0092	.0017	2 52 1.8	6.793	.410	+0.0158	+0.076	0.249	72.2	Fund catalogue	
6729	8.5	25 50.36	2.9603	.0016	5 8 21.9	7.337	.399	—0.003	—0.12	0.13	202.6	BZ1, BB1, Lam5	
6755	7.1	29 8.27	3.0152	.0021	2 38 20.3	7.605	.404	+0.0031	+0.086	0.098	29.2	D'A2, LZ1, BZ2	
6798	7.8	36 8.07	3.0446	.0027	1 17 46.9	8.168	.402	+0.011	—0.09	0.18	119.4	LZ1, BZ2. Lam6, BB1	
6861	9.1	43 52.55	3.0053	.0025	3 11 28.8	8.782	.390	—0.004	—0.16	0.17	200.5	BZ1, Lam1	Note 19
6893	8.5	47 55.38	3.0384	.0030	1 37 42.8	9.099	.391	+0.003	—0.32	0.32	171.1	BZ2, Lam3. Sj1	
6898	8.8	48 6.18	3.0384	.0030	1 37 33.4	9.112	.391	—0.001	—0.31	0.31	183.2	BZ2, Lam4	
6906	8.5	48 52.00	2.9960	.0025	3 40 16.8	9.172	.385	—0.005	—0.10	0.13	218.7	BZ2, Lam4	
6958	7.8	56 31.58	3.0115	.0029	2 58 29.7	9.763	.379	—0.007	+0.11	0.15	317.7	LZ1, BZ2, Lam5	
6973	7.0	58 50.76	3.0364	.0032	1 46 9.2	9.940	.380	—0.002	—0.14	0.14	192.1	LZ1, BZ1, R1, Lam5	G
6976	8.3	59 16.64	3.0083	.0029	3 9 11.9	9.972	.376	+0.006	—0.19	0.21	154.6	BZ2, Lam3	
7141	8.9	20 23 51.73	2.9790	.0028	4 55 22.6	11.778	.347	—0.008	—0.02	0.12	260.5	BZ1, Lam2, BB1	Note 20
7147	8.9	24 58.42	2.9819	.0029	4 47 27.7	11.857	.346	+0.017	+0.25	0.36	46.1	BZ1, Lam5, Sj.1	Note 21
7215	8.1	33 17.05	2.9891	.0030	4 31 48.1	12.435	.337	+0.0581	+0.090	0.873	84.1	LZ1, BZ2, BB9	A
7339	7.5	50 26.35	3.0509	.0041	1 14 37.6	13.577	.322	—0.0039	—0.225	0.233	194.7	LZ1, Pi, BZ1, Lam13	D
7352	5.6	52 49.70	3.0073	.0032	3 48 54.9	13.730	.314	—0.0109	—0.156	0.226	226.3	Br4-4	
7353	7.8	52 50.46	3.0072	.0032	3 48 57.8	13.731	.314	—0.006	—0.12	0.15	216.9	LZ2, BZ1, Lam3	Note 22
7373	7.7-8.1	56 42.43	3.0548	.0042	1 2 30.3	13.975	.314	—0.0101	—0.068	0.166	245.8	LZ2, BZ2, Str3	Note 23
7378	7.9	20 57 21.55	+3.0316	—0.0037	+2 26 12.6	+14.016	+0.310	—0.012	—0.08	0.20	246.0	BZ1, Lam1-2	

Alb. No.	Mag.	α 1875.0	Prec.	Sec. Var.	δ 1875.0	Prec.	Sec. Var.	Proper-Motion μ	Proper-Motion μ′	Proper-Motion Dist.	Proper-Motion Pos. Ang.	Authorities	Notes
	M	h m s	s	s	° ′ ″	″	″	s	″	″	°		
7382	8.5	20 57 49.74	+3.0140	−0.0033	+3 29 31.9	+14.045	+0.308	−0.006	−0.21	0.23	203.2	BZ1, Lam4	
7383	7.9	57 51.29	3.0304	.0037	2 30 47.1	14.047	.309	−0.023	−0.39	0.52	221.8	BZ1, Lam1	
7405	8.5	21 1 45.91	2.9877	.0028	5 9 10.5	14.289	.300	−0.003	−0.15	0.16	198.4	BZ2, Lam1	
7496	8.9	17 27.85	3.0557	.0041	1 5 5.8	15.219	.284	−0.010	−0.13	0.20	229.1	BZ3, Lam5	
7498	9.0	18 1.76	3.0239	.0033	3 11 3.3	15.251	.280	0.000	−0.15	0.15	180.0	BZ1, Lam3, Sj2	
7504	8.5	20 26.89	2.9986	.0026	4 54 36.2	15.388	.274	+0.010	−0.26	0.30	150.0	LZ1, BZ1, Lam1	D
7506	7.2	21 2.55	2.9997	.0026	4 51 5.6	15.421	.273	−0.005	−0.07	0.11	228.8	LZ1, BZ1, Lam2	
7562	6.3	32 16.27	2.9990	.0022	5 12 30.7	16.030	.256	+0.0069	+0.010	0.103	84.5	Br7–3	
7594	9.1	38 41.89	3.0363	.0031	2 39 47.2	16.362	.249	0.000	−0.19	0.19	180.0	BZ1, Lam1	
7631	8.5	45 45.54	3.0550	.0035	1 19 39.5	16.711	.239	−0.009	−0.19	0.23	214.4	BZ2, Lam7	
7650	8.8	50 40.22	3.0451	.0030	2 10 20.5	16.945	.230	−0.006	−0.23	0.25	202.2	BZ1, Lam4, BB1, Sj1	
7657	7.4	52 11.57	3.0329	.0025	3 11 9.7	17.016	.227	−0.019	−0.15	0.33	242.6	LZ2, BZ1, Lam1	D
7670	7.9	55 35.96	3.0219	.0020	4 10 21.8	17.172	.220	+0.003	−0.15	0.16	165.1	LZ1, BZ1	
7686	5.0	59 22.49	3.0200	.0018	4 26 54.0	17.340	.214	+0.0059	+0.085	0.123	46.3	Br2–3	
7692	8.2	22 0 8.35	3.0578	.0032	1 14 32.8	17.374	.215	+0.0205	+0.160	0.346	62.5	LZ1, BZ3, Lam9	A′
7710	7.5	3 41.17	3.0326	.0021	3 29 13.6	17.527	.207	+0.005	−0.07	0.11	131.2	LZ2, BZ1, BB4	
7727	8.2	7 46.07	3.0155	.0012	5 9 31.5	17.697	.199	−0.0061	−0.085	0.125	227.0	LZ2, BZ2	
7771	6.0	20 15.63	3.0352	.0013	3 45 24.5	18.185	.179	+0.0182	+0.029	0.275	84.0	Br4–5	
7776	5.6	21 31.89	3.0326	.0011	4 4 10.5	18.232	.176	+0.0043	−0.314	0.320	168.5	Br6–4	
7780	5.6	23 38.79	3.0360	.0012	3 47 51.4	18.308	.173	−0.0025	−0.146	0.151	194.2	Br4–3	Σ2912
7813	8.7	28 49.58	3.0539	.0018	2 1 33.2	18.188	.165	+0.009	+0.08	0.161	60.3	LZ1, BZ1, Lam4, BB1	
7842	6.9	34 6.62	3.0386	.0006	3 55 40.8	18.662	.154	+0.0049	−0.152	0.169	154.3	LZ2, BZ2, Lam1, Sj2	
7859	7.4	37 28.80	3.0457	.0008	3 13 11.5	18.768	.148	+0.0103	+0.359	0.391	23.2	LZ2, BZ2, Poulk2	D
7861	8.8	38 11.17	3.0378	.0003	4 13 5.3	18.790	.145	+0.004	−0.12	0.13	153.7	LZ2, BZ1, Sj1	
7882	7.7	41 45.36	3.0460	.0006	3 21 7.0	18.897	.141	−0.008	+0.03	0.12	284.0	LZ1, BZ1, BB2	
7888	8.6	42 59.55	3.0573	.0012	1 56 26.7	18.933	.139	−0.005	−0.12	0.15	213.7	LZ2, BZ1, Lam2	
7896	8.8	44 22.38	3.0630	−0.0015	1 13 0.4	18.972	.137	+0.003	−0.34	0.34	171.6	Lam4, Sj1	
7916	8.3	49 4.75	3.0427	+0.0002	4 9 8.2	19.102	.127	−0.004	−0.09	0.11	213.7	LZ2, BZ1, Sj2	
7938	6.7	52 58.01	3.0474	.0001	3 41 29.8	19.202	.120	−0.004	−0.09	0.11	213.7	LZ2, BZ1, Sj1	
7946	7.0	55 17.74	3.0475	+0.0003	3 47 37.1	19.260	.115	+0.0016	−0.126	0.128	169.2	LZ2, BZ1, BB4 [Sj1	
7960	7.7	57 42.39	3.0558	−0.0002	2 37 18.6	19.318	.111	+0.010	−0.09	0.175	120.9	LZ1, BZ1, AnnArbor1.	Note 24
7966	7.8	58 37.58	3.0502	+0.0004	3 33 25.6	19.339	.109	+0.010	−0.14	0.21	135.0	LZ1, BZ2	
7986	5.8	23 2 16.77	3.0638	−0.0005	1 26 51.6	19.422	.103	+0.0085	+0.102	0.163	51.2	Br10–5	
7990	8.2	3 10.90	3.0651	.0006	1 15 1.3	19.441	.101	+0.0060	−0.067	0.112	126.7	LZ3, BZ1, Lam1	
8007	8.6	5 54.97	3.0650	−0.0001	1 20 1.1	19.498	.096	+0.0056	−0.101	0.131	140.3	LZ1, Pi, BZ2, Lam6–5	
8009	8.0	6 15.37	3.0613	.0000	2 0 43.0	19.505	.095	+0.0008	−0.186	0.187	175.7	LZ3, BZ1, Lam3, R1, Sj2	
8036	1.0	10 41.13	3.0593	+0.0005	2 35 58.4	19.592	.087	+0.0492	+0.004	0.737	89.7	Fund. Catalogue	
8042	8.2	12 25.61	3.0599	.0006	2 33 57.9	19.624	.084	−0.0013	−0.111	0.113	190.2	D'A1, LZ2, BZ1, R4, Sj1	
8041	8.2	12 29.23	3.0495	.0017	4 43 31.3	19.625	.083	+0.0339	−0.112	0.519	102.5	LZ2, Pi, BZ1, BB4, Sj2	Sj A
8053	5.2	13 58.47	3.0503	.0017	4 41 57.2	19.651	.080	+0.0040	−0.082	0.102	143.8	Br11–6	
8074	8.5	19 58.77	3.0574	.0015	3 39 9.2	19.749	.069	−0.0039	−0.079	0.098	216.3	LZ2, BZ1, R2	
8079	8.5	20 58.81	3.0573	.0016	3 45 56.9	19.764	.067	−0.0010	−0.115	0.116	187.4	LZ2, BZ1, R1, Sj1	
8114	8.3	28 58.72	3.0674	.0009	1 31 24.2	19.871	.052	+0.004	+0.28	0.29	12.1	LZ1, Lam2, BB1	
8115	8.8	29 13.27	3.0618	.0019	3 21 7.1	19.874	.051	+0.002	−0.13	0.13	167.0	BZ2, Sj2	
8121	6.0	30 0.65	3.0679	.0009	1 24 32.0	19.883	.050	−0.0077	+0.051	0.126	293.9	Br12–4	
8132	4.3	33 31.30	3.0589	.0030	4 56 56.2	19.921	.043	+0.0239	−0.443	0.570	141.1	Fund. Catalogue	
8141	5.0	35 40.05	3.0695	.0011	1 5 31.7	19.941	.039	−0.0101	−0.165	0.224	222.5	Br12–6	
8160	8.1	41 26.04	3.0657	.0027	3 28 55.0	19.988	.028	+0.022	−0.02	0.33	93.5	LZ1, BZ1, R2 [Sj1	
8164	8.8	42 40.47	3.0692	.0018	1 14 24.0	19.997	.025	+0.0614	−0.947	1.322	134.5	LZ1, BZ1, Lam1, BB8, A Sj	
8170	8.3	43 38.15	3.0686	.0021	2 10 34.4	20.003	.023	+0.027	+0.19	0.44	64.6	Lam2, BB1	
8198	8.3	23 49 10.26	+3.0691	+0.0028	+2 48 57.9	+20.032	+0.013	−0.0153	−0.257	0.344	221.7	LZ1, Pi, BZ1, Kg2	

Note 1, No. 104. This star may be variable. The Albany estimates, six in number, vary from $8^M.0$ to $6^M.5$, with the mean $7^M.3$. The *Durchmusterung* has $8^M.0$; D'AGELET, PIAZZI, BESSEL and RUMKER, each 7^M.

Note 2, No. 439. The value of μ' is uncertain; from BZ it is $-0''.11$, and from RÜMKER, $-0''.25$.

Note 3, No. 501. From BZ, $\mu = +0^s.012$, and from Sj, $-0^s.012$. If we assume that BZ gives the R.A. 1^s too small, μ from BZ then becomes $-0^s.005$, and $+0^s.007$ may be regarded as the most probable value of μ. In the uncertainty it appears best not to assign the direction and amount of proper-motion.

Note 4, No. 676. BOSSERT in the Introduction of the Paris catalogue gives $\mu = +0^s.0160$. The R.A. of LZ is probably 1^s too great.

Note 5, No. 1342. From two observations of BZ we have: $\mu = +0^s.011$, and from Sj, $-0^s.005$.

Note 6, No. 2511. See *Astronomical Journal*, No. 170.

Note 7, No. 2958. The *Durchmusterung* gives 8.0 as the magnitude of this star. The five Albany estimates agree well.

Note 8, No. 4614. The companion, $8^M.4$ at dist. $8''$, position-angle 4°, probably has the motion of the principal star.

Note 9, No. 4772. D'Agelet's declination is possibly $30''$ too great.

Note 10, No. 1915. This is the mean of a close double, —Σ1819.

Note 11, No. 5114. From Lamont results: $\mu = +0^s.007$: from Lalande, $\mu' = -0''.04$. The proper-motion must therefore be regarded as quite uncertain.

Note 12, No. 5551. Rejecting Bradley's observation we should have: $\mu = -0^s.004$.

Note 13, No. 5592. From BZ (2 obs.) $\mu = -0^s.001$, and after increasing Lamont's R.A. by 1^s, from Lamont $\mu = +0^s.008$. Bessel's observations differ $0^s.47$ in R.A. The proper-motion for this star is, therefore, quite uncertain.

Note 14, No. 5786. From Lamont, $\mu' = -0''.44$: from Rümker, $-0''.22$. The intervals from Albany observations are respectively 33 and 40 years. The observation by Rümker is contained in the *Nachtrag* to 17^h.

Note 15, No. 5952. The R.A. of BZ is increased 1^s with μ from it, $-0^s.013$. From LZ, $\mu = -0^s.007$; from Lamont, $\mu = -0^s.013$. If BZ be not corrected we have from it, $\mu = +0^s.005$. It is quite possible that this is the more correct assumption, and that μ is very nearly $0^s.000$.

Note 16, No. 5957. μ' is very uncertain.

Note 17, No. 6275. From BZ, $\mu = +0^s.002$; from Lamont, $-0^s.012$ ($\Delta ep = 32$ years). μ is therefore rather uncertain.

Note 18, No. 6133. From Pi, $\mu' = -0''.12$; from BZ, $-0''.10$; from Lamont, $0''.08$. Assuming the declination of Lalande to be $10''$ too great, $\mu' = -0''.11$, and if it is considered to be $15''$ too great, $\mu' = -0''.05$; from Lalande uncorrected, $\mu' = -0''.23$. In computing μ' Lalande's δ was rejected.

Note 19, No. 6861. It was assumed that Bessel's R.A. ought to be diminished 1^s; from it without correction results: $\mu = -0^s.021$.

Note 20, No. 7141. From Bonn VI results: $\mu' = -0''.18$. No use is made of this value.

Note 21, No. 7147. This is the mean of a close double.

Note 22, No. 7353. It is quite probable that the motion of this star is equal to that of No. 7352, with which it is associated to form Σ2737.

Note 23, No. 7373. This is the mean of a close double, Σ2744.

Note 24, No. 7960. From LZ, $\mu = +0^s.012$; from the Ann Arbor position, $\mu = +0^s.012$; from Sj, $+0^s.007$; from BZ uncorrected, $\mu = -0^s.001$, and if the R.A. of BZ be diminished 1^s, $\mu = +0^s.016$. The latter is probably the correct assumption; but in the computation of μ, BZ is rejected.

The preceding catalogue fails to contain Sj. 8186. Schjellerup assigns a proper-motion in R.A. of $-0^s.059$; but it is probable that Bessel's R.A. is 1^s too great, and Schjellerup's 1^s too small. The proper-motions assigned by Grant to Glasgow numbers 1355 and 2326, appear also to have no existence, since they are based upon gross errors in Weisse's catalogue. I have found it necessary to apply large systematic corrections to certain zones of Lalande and Bessel (*Astr. Jour.*, No. 195), and for this reason, principally, some of the proper-motions computed by me do not accord well with those for the same stars published in the Glasgow and Paris catalogues and elsewhere.

NOTE ON THE RING-NEBULA IN *LYRA*,

BY A. HALL.

In the summer of 1877 I measured some of the faint stars that form a ring round this nebula, referring the positions of these faint stars to the brightest star of the group, which is near the following end of the nebula (*Astr. Nachr.* 2186). At that time I could not see any star inside the nebula. In the following summer, Mr. A. C. Ranyard of London, visited the Naval Observatory, and I find by our observing-book, that he examined this nebula with our 26-inch refractor, and saw a small star near the center of this nebula. This was on August 23, 1878.

Naval Observatory, 1889 *May* 13.

OBSERVATIONS OF COMETS *d* AND *e* 1889, AT THE LICK OBSERVATORY.

A dispatch from Prof. Holden, July 27, gives the following position, obtained at the Lick Observatory, of comet *e* 1889 (Davidson, *July* 22):

1889 July 26.6822 Greenw. M.T., $\alpha = 13^h\ 29^m\ 36^s.6$, $\delta = -22°\ 1'\ 13''$.

Another dispatch, August 3, states that Prof. Barnard, in observing comet *d* 1889 (Brooks, *July* 6) on the night of Thursday, August 1, found it composed of three separate comets all within three minutes of arc; that the discovery was confirmed on the next evening; and that the number of the comets perhaps exceeds three.

CONTENTS.

Proper-Motions of Stars in the Albany Zone (+0° 50′ to 5° 10′ for 1855), by Prof. Lewis Boss.
Note on the Ring-Nebula in Lyra, by Prof. A. Hall.
Observations of Comets *d* and *e* 1889, at the Lick Observatory.

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CORDOBA OBSERVATIONS OF η *ARGÛS.*

BY JOHN M. THOME.

Frequent examinations of this object during the years 1885 and 1886 showed that its light was diminishing by a gradual but almost inappreciable quantity, and it had reached a point midway between BRISBANE 3201 ($7^M.55$?) and GILLIS 1332 ($7^M.78$?) in July of the latter year. My attention was not directed to it again until the night of March 20, 1887, when I at once noticed a change in its appearance, more like that of a dying ember that had begun to glow again than as an actual change in brilliancy; of which, however, I felt confident, though not able to prove it conclusively. A few weeks' observation were, however, sufficient to convince me of the change, and there has since that time been a uniform increase in brightness, until the object is now easily visible to the naked eye, having a magnitude of 6.66, or a shade fainter than LACAILLE 4481.

It is evident, therefore, that the change took place before March 20, 1887, and it is probable that a period between the last observation of 1886 and this one, or near the end of the year 1886, would closely coincide with the minimum of light.

Since the beginning of 1888, when it had attained a brightness sufficient to bring it within the reach of our photometer (ZÖLLNER'S), I have made various attempts to fix its magnitude upon the scale of the *Uranometria Argentina*, and the results obtained are given herewith. The object was, however, too faint for our glass, especially at the beginning of the series, to permit of entirely satisfactory measures; but there seems to be no indication of a fluctuation in brightness, which is in accord with my estimates by sequences, using the equatorial (11-inch) and finder.

The photometric determinations are as follows:

	1888					1889				
	Apr. 25	May 9	May 30	June 26	Oct. 10	Mar. 19	May 20	June 23	Means	U. A.
Lac. 4479	7.00	6.96	6.82	6.94	7.00	–	–	–	6.92	7.0
" 4448	7.05	7.01	–	6.90	6.90	–	–	–	6.97	6.9
η *Argûs*	6.98	6.85	6.90	6.87	6.77	6.69	6.66	6.66	–	Var.
" 4422	6.87	–	–	6.90	–	–	–	–	6.88	7.0
" 4451	–	–	6.81	6.81	6.80	6.82	6.80	–	6.81	6.8
" 4481	6.59	6.65	6.55	6.64	6.60	6.60	6.60	6.62	6.60	6.7
" 4493	–	–	–	–	–	6.16	6.16	6.18	6.17	6.7

Various attempts have been made to extend the scale to include GILLIS 1332, but our small object-glass (70 mm) and the poor skies have hitherto given unsatisfactory results. The ranges are between $7^M.78$ and $7^M.85$.

During the year 1885, I also made a series of photometric determinations of the magnitudes of the brightest stars, with satisfactory results. The ZÖLLNER is provided with a planet telescope, with which the light of the stars can be stopped down to a convenient quantity, and it is easy to substitute another tube when desired. The stars were divided into groups, each having two or three stars in common with the one next below; and the last group, the standard, consisted principally of stars whose magnitudes had been carefully determined for the Uranometry. The measures were all made at the same altitude, as nearly as possible, and corrected for extinction at lower ones. The resulting magnitudes are given for the brightest stars:

α *Can. Majoris*	—1.2	α *Crucis*	0.93
η *Argûs*	?	α *Tauri*	1.08
α *Carinae*	—0.6	α *Virginis*	1.13
α *Centauri*	0.0	α *Piscis Austr.*	1.26
α *Bootis*	+0.23	α *Leonis*	1.35
β *Orionis*	0.34	γ *Orionis*	1.71
α *Eridani*	0.48	ζ *Orionis*	1.92
α *Can. minoris*	0.78	δ *Orionis*	2.[illegible]8
β *Centauri*	0.85		

If, therefore, we fix the minimum of η *Argûs* at the end of 1886, with a magnitude of 7.65, and its maximum, as given by Maclear, in 1843, between *Sirius* and *Canopus*, or —1.0, approximately, we shall have a range of 8½ stellar magnitudes (instead of 6, as heretofore assumed) in a period of 43 or 44 years, or an average rate of nearly 0.2 magnitude per year.

Among the trustworthy records of former observations, we find:

			M
Gillis,	1850.1,	η between *Canopus* and *α Centauri*.	—0.3?
"	1852.0.	η equal to *α Centauri*.	0.0
Herschel,	1838?,	η " "	0.0
Maclear,	1843?,	η between *Sirius* and *Canopus*,	—1.0?
Fallows,	1822–26,	η 2d magnitude, probably, 1822, $2^{M}.4$; 1824, $2^{M}.0$; 1826,	1.6
Burchell,	1827,	η equal to *α Crucis*,	1.0?
Burchell,	1811–15,	η 4th magnitude, probably, 1811. $4^{M}.4$; 1813, $4^{M}.0$; 1815,	3.6
Johnson,	1832,	η 2d magnitude. Indefinite. If he classed *Sirius*, *Canopus* and *α Centauri* as 1st magnitude, his second might begin with $0^{M}.6$ of this scale: equal to *α Canis minoris* for instance.	

Cordoba, 1889 *June* 25.

Lacaille's 2d magnitude in 1751, and Halley's 4th in 1677, cannot be reconciled except upon the supposition of secondary maxima, or of errors of observation. If, as seems probable, we have here a meteor swarm accompanied by a satellite swarm, fluctuations in brightness about maximum, and a regular decline while approaching minimum, would be expected.

I append, also, the estimates made by Powell and Tebbutt, without knowing, however, what their comparison-stars were, nor how closely the scale agrees with the homogeneous one of the *Uranometria Argentina*.

Powell, 1856, $1^{M}.5$(?); 1859, $3^{M}.0$; 1861, $3^{M}.6$.

Tebbutt, 1862, $4^{M}.9$; 1863, $5^{M}.1$; 1865, $5^{M}.2$; 1866, $5^{M}.8$; 1867.5, $6^{M}.0$; 1888.3, $7^{M}.0$ (*U.A.* scale).

Cordoba, 1871, $6^{M}.6$; 1878, $7^{M}.4$; 1881, $7^{M}.5$; 1885.0, $7^{M}.62$; 1886.5, $7^{M}.65$; 1887.25, increasing; 1887.3, $7^{M}.6$; 1887.4, $7^{M}.5$; 1887.5, $7^{M}.4$; 1887.6, $7^{M}.2$; 1888.1, $7^{M}.1$; and, as above; all *U.A.* scale.

If the estimated magnitudes given above could be reduced to a homogeneous scale, especially where the comparison-stars are named, it might be possible to deduce an approximate period, which would answer until a new maximum disproved it.

COMET *e* 1889 (*DAVIDSON*).

By E. E. BARNARD, Astronomer of the Lick Observatory.

The telegram announcing the discovery of this comet was received on July 25. That evening it was easily found, but the eye-end of the 12-inch being away for repairs, and the comet being out of reach of the other telescopes, no accurate place could be obtained. However, five pointings with the finder of the 12-inch, corrected by pointings on γ *Hydrae*, gave the place of the comet pretty closely,

Mt. Hamilton M.T.	App. α	App. δ
d h m s	h m s	° ′
July 25 9 8 53	13 19 9	—24 16

As seen in the finder (3¼-inch) the comet was large and bright, with a bushy tail. It was easily visible to the naked eye, appearing as a large oblong nebulous mass as bright as a 6th magnitude star.

On the evening of July 26, I fitted the micrometer by a temporary tube to the telescope, and secured the positions of July 26 and 29 given below.

On July 30, a camera box and large portrait lens were strapped to the telescope tube. With an eyepiece magnifying 190 diameters, which was provided with two cross wires, I followed the nucleus for 1^{h} 30^{m} while the comet was exposed to a Seed No. 26 plate. The extremely rapid motion of the comet in both coordinates required the instrument to be constantly shifted in R.A. and Decl. to keep the image stationary on the plate.

Upon development, the picture proved to be very successful; the nucleus was sharp and round, and the coma strongly marked. Upon the plate the tail was conspicuous for 20′, and could be traced with certainty for nearly one degree. It was fan-shaped, and somewhat convex toward the axis. The accuracy with which the telescope was kept pointed on the nucleus is seen by the sharpness and uniformity of the star trails — the amount of motion of the comet being strikingly shown by the lengths of these trails (about 14′ long). A number of standard squares having been impressed on the plate from the standard lamp used in the photometric work of the last solar eclipse (procured for the Observatory through the kindness of Professor Pickering, and exactly like the standard lamp of the H.C.O.), gave the means of determining the intrinsic actinic brilliancy of the comet's light.

The brightness of the comet 2′ or so from the head has been compared with the squares by Professor Holden, and he finds the intrinsic brilliancy of the comet's actinic light to be

0.000,000,15 units of the S.L.

The full moon has an intrinsic brilliancy of 1.66 units, according to the determinations of Mr. W. H. Pickering; and the brightest parts of the corona of January 1889 had an intrinsic brilliancy of 0.08 units, according to the results given in the Lick Observatory Report on that eclipse.

Hence the corona of last January was at least 500,000 times brighter intrinsically than the comet, and the full moon is at least 10,000,000 times brighter.

These photometric results still require correction for the absorption of the lens, which has not yet been determined, as it has just come into our possession.

On July 26, the comet was more conspicuous to the eye than a star of the sixth magnitude.

On August 1, I compared it with the naked eye, with the great nebula of *Andromeda*, which was at nearly the same altitude in the east. The comet very much resembled the nebula in form and brightness, but was perceptibly less bright and smaller. I should say that it was about four-fifths as large and four-fifths as bright as the nebula, but the sky was somewhat luminous with the moon, which was above the horizon, and near the comet.

At most the comet has been slightly inferior in size and brightness to the great nebula, and singularly like it in form.

The following are the observations so far obtained.

OBSERVATIONS OF COMET *e* 1889 *(DAVIDSON)*,

MADE WITH THE 12-INCH EQUATORIAL OF THE LICK OBSERVATORY.

BY E. E. BARNARD, ASTRONOMER.

1889 Mt. Hamilton M.T.	⁎	No. Comp.	☄ — ⁎ Δα	☄ — ⁎ Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
d h m s			m s	′ ″	h m s	° ′ ″		
July 26 8 15 52	1	9 , 8	+0 15.75	+1 53.1	13 29 36.57	—22 1 13.5	9.566	0.831
29 8 55 19	2	12 , 6	—0 2.51	+1 27.9	13 58 37.66	—13 36 30.9	9.583	0.793
Aug. 5 8 36 17	3	23 , 8	+0 0.24	—1 35.1	14 48 11.66	+ 2 12 12.2	9.502	0.712

Mean Places for 1889.0 of Comparison-Stars.

⁎	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	13 29 20.38	+0.44	—22 2 59.1	—7.2	Bonn VI, —21 46
2	13 58 39.45	+0.75	—13 37 55.1	—3.7	Lamont 1456
3	14 48 10.17	+0.95	+ 2 13 44.2	+3.4	Comp. with W.B. 14ʰ 885

W.B. 14ʰ 885, — ⁎3 = —0ᵐ 22ˢ.03, —22′ 0″.6.

SOLAR OBSERVATIONS AT SHATTUCK OBSERVATORY.

BY EDWIN B. FROST.

I. OBSERVED SPOTS.

1889	E.S.C.T.	No. of Groups	No. of Spots	No. of New Gr'ps	No. of New Spots
	h m				
Feb. 1	11 45	1	4	1	4
25	11 30	1	4	1	4
26	12 30	1	6	0	2
28	14 15	1	10	0	4
Mar. 1	12 0	1	3	0	0
11	11 15	2	5	2	5
13	14 30	2	8	1	3
14	14 0	2	8	0	0
16	17 0	1	2	0	0
April 1	12 0	1	1	1	1
5	11 30	1	1	0	0
6	13 15	1	1	0	0
7	13 30	1	1	0	0
8	11 30	1	1	0	0
10	13 30	1	1	0	0
11	9 50	2	4	1	3
16	11 15	1	1	1	1
17	12 0	1	1	0	0
May 5	16 0	1	1	1	1
6	11 15	1	1	0	0
7	10 0	1	3	0	2
8	11 30	1	7	0	4
9	10 40	1	3	0	0
June 15	17 0	1	1	1	1
16	15 0	2	2	1	1
17	17 50	1	6	0	4
18	13 50	1	6	0	0
19	11 0	1	9	0	3
20	12 30	2	6	0	0
21	14 30	2	8	0	2
22	14 15	2	12	0	6
23	16 35	4	15	0	3
27	12 35	1	1	0	0
30	17 40	1	1	1	1
July 1	10 30	1	1	0	0
Totals	35 days	13	145	12	55

The hours are expressed in Eastern Standard Civil Time,* reckoned from mean midnight. The aperture of the equatorial is 9.4 inches, and the magnifying power of the eye-piece is 50. The observations are made on the projected image, which has a diameter of from 20.6 to 21.0 cm. The observations of April 5–10 and May 5 and 7 are by students of the college.

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* *i.e.*, Greenwich M.T., less 5ʰ.

II. APPROXIMATE HELIOGRAPHIC LATITUDE AND LONGITUDE OF THE CHIEF SPOT OF EACH OBSERVED GROUP.

Group Number	No. of Spots	1889	E.S.C.T. h m	λ °	l °
1	4	Feb. 1	11 45	S 7.5	32.8
2	4	25	11 30	S 9.2	114.7
2	10	28	14 45	S 8.8	113.5
2	3	Mar. 1	12 0	S 9.5	112.9
3	1	11	14 45	N . .	. . .
4	7	14	14 0	N 2	312
4	2	16	17 0		
5	1	14	14 0	S 12	319.5
6	1	April 4	12 0	N 5.5	315.8
6	1	8	11 30	N 5.9	310.5
7	3	April 11	9 50	S 11.2	204.6
8	1	16	11 15	S 6.1	224.4
9	1	May 6	12 0	N 0.96*	217.12*
9	7	8	12 0	N 0.29*	218.52*
10	1	June 19	11 15	S 5.87*	29.96*
10	2	20	12 30	S 6.13*	29.64*
10	15	23	16 35	S 5.1	32.8
11	4	20	12 30	S 6.17*	21.06*
12	1	30	17 40	S 39.8	250.0
12	1	July 1	11 30	S 12.41*	250.07*

The values of λ and l were obtained from measurement of the diagrams of the projected image. Of course any error in orientation will enter into the result, so that the values given cannot pretend to any great accuracy. I have given the results for the same spot on different days, however, in order that an idea may be gained of their consistency. Those marked with an asterisk were obtained by CARRINGTON'S method, and are to be considered quite accurate. The factors for reduction were taken from the "Companion to the Observatory." Of the 12 groups, 4 are north of the equator, comprising 17 of the 55 observed spots. The mean latitude of the north spots is only about 3°, while that of the southern is nearly 13°.

The last spot on the list was first observed late in the afternoon of June 30, not having been visible on the previous day, and cannot be classed as a "veiled" spot. It had a conspicuous umbra, but no penumbra, and was independent of any faculae. A diagram was hastily made, and on the next morning its position was more accurately obtained by CARRINGTON'S method, although clouds interfered considerably. The spot was barely visible at 15h (July 1), and had disappeared an hour later. This spot is to be considered as evidence that the minimum is nearly, if not quite, reached.

III. OBSERVATIONS ON THE FOLLOWING DATES SHOWED NEITHER SPOTS, NOR, EXCEPT IN CASES INDICATED BY THE LETTER *f*, BRIGHT FACULAE.

1889	h	m	1889	h	m	1889	h	m	1889	h	m	1889	h	m	1889	h	m
Jan. 8	12	30	Feb. 15	16	15	Mar. 30	14	40	Apr. 27	11	15	May 18	11	0*f*	June 4	16	30
18	15	0	20	14	0	Apr. 13	16	15	30	17	20	19	12	45	5	14	40
19	12	0	21	12	15	14	14	50	May 3	17	20	22	11	0	6	11	20
20	11	50	Mar. 4	12	0*f*	15	12	30	4	12	10	23	13	20	7	11	30
22	10	45	21	14	55	18	12	0	11	11	55	24	17	45	9	17	15
23	15	30	22	14	30	19	11	20	12	12	30	25	11	0	10	11	0
25	15	30	23	17	0	20	13	10	13	13	30	28	10	0	11	11	30*f*
Feb. 4	14	30	24	8	10	21	14	20	14	18	0	29	12	15	13	11	30*f*
9	15	0	25	8	30	22	13	30	15	13	15*f*	31	15	0	14	12	0
13	12	30	26	12	30	23	11	15	16	16	30	June 2	12	30	28	12	30
14	12	30	29	13	30*f*	26	14	0	17	11	50*f*	3	13	45	29	12	30
															66 days		

The first observation of the above list, I made with the 9-inch Princeton equatorial, through the courtesy of Prof. YOUNG. The observations of Jan. 25, Feb. 4 and 9, May 12 and 19, and June 2, were made by students. On April 20 and 27, I saw extremely minute pinules, — too small to be called spots. The longest interval without a spot is from May 9–June 15, 37 days.

Dartmouth College, Hanover, N.H., 1889 *July* 8.

The spectroscope was used in observing prominences on 41 days.

Seven observations in March, with rather poor seeing, showed no prominences over 15″ in height. Eleven observations in April give a mean number of prominences per observation 2.3. From thirteen observations in May, and eight in June, the mean numbers are respectively 3.5 and 1.1.

TWO HUNDRED EIGHTY-FIFTH ASTEROID.*

A planet of the thirteenth magnitude was discovered by PALISA at Vienna, August 3. Its position was

1889 Aug. 3.4972 Gr. M.T. $\alpha = 22^h\, 13^m\, 52^s.9$. $\delta = -9^\circ\, 1'\, 23''$. Daily motion, -36^s in α, and 7′ southward.

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* Printed in a Supplement issued with No. 200.

TWO HUNDRED EIGHTY-SIXTH ASTEROID.*

A planet of the thirteenth magnitude was discovered by Charlois at Nice, August 3. Its position was 1889 Aug. 3.4917 Gr. M.T. $\alpha = 21^h\ 23^m\ 24^s.5$, $\delta = -13°\ 4'\ 22''$. Daily motion, -60^s in α, and 4′ northward.

OBSERVATIONS OF COMET *d* 1889 (*BROOKS, July 6*).*

MADE WITH THE 15-INCH EQUATORIAL OF THE HARVARD COLLEGE OBSERVATORY.

By O. C. WENDELL, Assistant.

[Communicated by Prof. Edward C. Pickering, Director.]

1889 Greenwich M.T.	*	No. Comp.	☄ — * Δα	☄ — * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
d h m s			m s	′ ″	h m s	° ′ ″		
July 20 17 55 48	1	5	−2 13.92	+2 20.9	23 57 2.75	−7 51 9.1	n9.172	0.816
23 17 50 57	2	5	+0 25.47	−2 7.1	59 16.06	−7 36 50.7	n9.461	0.816
24 16 53 1	2	5	+1 4.54	+2 16.8	23 59 55.16	−7 32 26.7	n9.557	0.805
25 17 49 32	2	5	+1 45.89	+6 53.6	0 0 36.54	−7 27 49.8	n9.450	0.816

Mean Places for 1889.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place.	Authority
	h m s	s	° ′ ″	″	
1	23 59 15.37	+1.30	−7 53 41.0	+11.0	Schjellerup 9984
2	23 58 49.20	+1.39 +1.42 +1.45	−7 34 55.0	+11.4 +11.5 +11.6	Weisse's Bessel 23h 1170

EPHEMERIS OF COMET *b* 1889.*

By W. W. CAMPBELL.

The morning appearance of this comet was noted here July 22, but there was insufficient time to fix its position. From an observation made on July 25 the corrections to my ephemeris in *Astr. Jour.* 197, were found to be -6^s and $-1'.8$. The following continuation of that ephemeris will therefore represent the path of the comet sufficiently well for purposes of observation.

Ephemeris for Greenwich Mean Time.

1889	App. α	App. δ	log r	log Δ	Br.
	h m s	° ′			
Aug. 6.5	5 1 41	+8 53.2	0.3731	0.4300	0.92
8.5	5 0 34	8 35.8	0.3746	0.4240	
10.5	4 59 19	8 17.7	0.3758	0.4189	0.96
12.5	4 57 58	7 58.8	0.3771	0.4128	
14.5	4 56 29	7 39.1	0.3784	0.4067	1.01
16.5	4 54 52	7 18.5	0.3797	0.4005	
18.5	4 53 8	6 57.0	0.3811	0.3941	1.05
20.5	4 51 14	6 34.5	0.3825	0.3876	
22.5	4 49 12	6 11.0	0.3839	0.3810	1.10
24.5	4 47 0	5 46.4	0.3854	0.3742	
26.5	4 44 37	5 20.8	0.3869	0.3673	1.16
28.5	4 42 1	4 54.0	0.3884	0.3604	
30.5	4 39 19	4 26.0	0.3899	0.3533	1.22
Sept. 1.5	4 36 23	3 56.9	0.3914	0.3462	
3.5	4 33 11	3 26.4	0.3930	0.3391	1.29
5.5	4 29 51	+2 51.7	0.3946	0.3319	
Sept. 7.5	4 26 16	+2 21.7	0.3962	0.3248	1.35
9.5	4 22 27	1 47.3	0.3979	0.3177	
11.5	4 18 22	1 11.7	0.3995	0.3107	1.42
13.5	4 14 2	+0 34.6	0.4012	0.3038	
15.5	4 9 29	−0 3.7	0.4029	0.2970	1.49
17.5	4 4 39	0 43.3	0.4046	0.2905	
19.5	3 59 33	1 24.1	0.4064	0.2842	1.55
21.5	3 54 10	2 6.1	0.4081	0.2782	
23.5	3 48 32	2 49.2	0.4099	0.2725	1.61
25.5	3 42 37	3 33.2	0.4117	0.2672	
27.5	3 36 27	4 17.8	0.4135	0.2623	1.66
29.5	3 30 2	5 3.1	0.4153	0.2579	
Oct. 1.5	3 23 22	5 48.9	0.4171	0.2541	1.70
3.5	3 16 28	6 34.8	0.4189	0.2509	
5.5	3 9 23	7 20.5	0.4208	0.2483	1.70
7.5	3 2 7	8 5.9	0.4227	0.2464	
9.5	2 54 41	8 50.6	0.4245	0.2451	1.71
11.5	2 47 7	9 34.4	0.4264	0.2446	
13.5	2 39 28	10 17.0	0.4283	0.2449	1.68
15.5	2 31 45	10 58.1	0.4302	0.2459	
17.5	2 23 59	11 37.5	0.4321	0.2477	1.63
19.5	2 16 11	12 15.0	0.4340	0.2501	
21.5	2 8 32	−12 50.3	0.4360	0.2534	1.56

Ann Arbor, 1889 *August* 3.

[*Correction:* — An erroneous value of the unit was employed in computing the brightness for the ephemeris in *Astr. Jour.* 197.]

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OCCULTATION OF *JUPITER*, 1889 SEPTEMBER 3.

By WILLIAM BELLAMY.

The accompanying table gives, for places at intervals of 4° in latitude and 5° in longitude, the Greenwich mean times of immersion and emersion of *Jupiter's* center; also its angle from the north point of the moon's disk at emersion.

The first contact of the disks precedes about one minute, and the first occultation of a satellite (the third) precedes about fifteen minutes, the time of occultation of the center.

Immersion.

Lat. N.	Longitude West from Greenwich.											
	125°	120°	115°	110°	105°	100°	95°	90°	85°	80°	75°	70°
°	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
46	13 25	13 31	13 37	13 44	13 52	14 0	14 9	14 17	14 26	14 33	14 41	14 48
42	26	32	38	46	54	3	12	22	31	40	49	56
38	30	34	41	49	57	7	17	27	37	47	57	
34		40	46	53	14 2	13	23	35	46	58	15 11	
30					11	21	33	46	15 0			

Emersion.

Lat. N.	Longitude West from Greenwich.											
	125°	120°	115°	110°	105°	100°	95°	90°	85°	80°	75°	70°
°	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
46	14 29	14 38	14 47	14 56	15 5	15 13	15 20	15 26	15 32	15 36	15 39	15 42
42	25	36	46	56	6	14	22	28	34	38	41	43
38	19	32	44	55	5	14	23	30	35	38	41	
34		25	39	52	3	13	21	28	33	36	35	
30					14 58	9	17	23	25			

Angle from North Point.

Lat. N.	Longitude West from Greenwich.											
	125°	120°	115°	110°	105°	100°	95°	90°	85°	80°	75°	70°
°	°	°	°	°	°	°	°	°	°	°	°	°
46	248	252	254	255	255	254	253	250	247	243	238	233
42	241	245	248	249	249	248	246	243	239	235	229	223
38	231	236	240	242	242	241	238	235	230	224	217	
34		224	230	232	232	231	228	224	218	210	199	
30					220	218	215	209	199			

ORBIT OF COMET *e* 1889 (*DAVIDSON*).*

By T. H. SAFFORD.

The elements below were computed from the observations of July 22 and 26 (pp. 56 and 64), and the following additional position by Barnard at the Lick Observatory:

1889 Aug. 5.6964 Gr. M.T.

$\alpha = 14^h\ 48^m\ 11^s.7, \qquad \delta = +2^\circ\ 12'\ 12''$

Elements.

$T = $ 1889 July 19.1638 Gr. M.T.

$\omega = 345^\circ\ 43'.62$

$\Omega = 286\quad 6.11$

$i = 66\quad 14.66$

$\log q = 0.01692$

(C—O), $\Delta\lambda\cos\beta$, $+1'.2$, $\Delta\beta$, $+2'.1$

Equatorial Coordinates.

$x = r\,(9.67774)\ \sin(v + 21^\circ\ 21'.07)$

$y = r\,(9.96353)\ \sin(v + 239\ \ 10.97)$

$z = r\,(9.98375)\ \sin(v + 322\ \ 20.18)$

Ephemeris for Greenwich Midnight.

1889	α	δ	Br.
	h m	° ′	
August 7	14 58.0	+ 5 19	0.49
11	15 16.7	11 1	0.37
15	15 32.1	15 23	0.27
19	15 45.2	18 46	0.21
23	15 56.7	21 26	0.16
27	16 6.9	23 35	0.13
31	16 16.2	+25 20	0.10

Light at discovery = 1.

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* Printed in a Supplement issued with No. 200.

ELEMENTS AND EPHEMERIS OF COMET *e* 1889 (*DAVIDSON*).*

By WILLIAM BELLAMY.

Computed from the Australian position of July 22. and those made at the Lick Observatory July 26 and Aug. 5.

$$T = 1889 \text{ July } 19.1532 \text{ Gr. M.T.}$$

$$\left.\begin{aligned}\omega &= 345^\circ\ 12'\ 39''\\ \Omega &= 286\ \ \ 5\ \ 46\\ i &= \ 66\ \ 14\ \ 52\end{aligned}\right\}\ 1889.0$$

$$\log q = 0.01690$$

(C—O). $\Delta\lambda\cos\beta$, $+1'.0$, $\Delta\beta$, $+2'.1$

Dorchester, Mass., 1889 *August* 8.

Ephemeris for Greenwich Time.

1889	α h	α m	α s	δ °	δ ′	log *r*	log Δ	Br.
Aug. 13.5	15	21	14	+13	20	0.0501	9.7758	0.33
15.5		32	7	15	23	0.0554	9.8015	0.28
17.5		38	54	17	11	0.0606	9.8261	0.25
19.5		45	11	18	16	0.0660	9.8503	0.22
21.5		51	9	20	11	0.0716	9.8729	0.19
23.5	15	56	12	21	27	0.0773	9.8917	0.17
25.5	16	1	58	22	35	0.0832	9.9155	0.15
27.5		6	58	23	34	0.0892	9.9353	0.13
29.5		11	45	24	29	0.0954	9.9512	0.12
31.5	16	16	21	+25	18	0.1016	9.9723	0.11

After the appearance of the above in the Supplement to No. 200, the elements were slightly improved, and the ephemeris is here continued.

Ephemeris for Greenwich Time.

1889	α h	α m	α s	δ °	δ ′	log *r*	log Δ	Br.
Aug. 31.5	16	16	41	+25	24	0.1012	9.9707	.102
Sept. 2.5		21	10	26	9	0.1075	9.9881	
4.5		25	30	26	50	0.1139	0.0016	.082
6.5		29	42	27	28	0.1203	0.0201	
8.5		33	49	28	2	0.1267	0.0356	.067
10.5		37	51	28	34	0.1331	0.0501	
12.5		41	49	29	4	0.1396	0.0641	.053
14.5		45	44	29	31	0.1460	0.0775	
16.5		49	37	29	56	0.1525	0.0904	.046
18.5		53	27	30	20	0.1590	0.1028	
20.5	16	57	16	30	42	0.1654	0.1147	.039
22.5	17	1	4	31	2	0.1719	0.1262	
24.5		4	50	31	22	0.1782	0.1373	.033
26.5		8	37	31	40	0.1845	0.1480	
28.5	17	12	23	+31	58	0.1908	0.1584	.028
Sept. 30.5	17	16	10	+32	15	0.1971	0.1685	
Oct. 2.5		19	56	32	31	0.2033	0.1782	.024
4.5		23	43	32	46	0.2095	0.1876	
6.5		27	31	33	1	0.2156	0.1967	.021
8.5		31	19	33	15	0.2216	0.2055	
10.5		35	9	33	29	0.2276	0.2141	.019
12.5		38	59	33	43	0.2335	0.2224	
14.5		42	50	33	56	0.2394	0.2305	.017
16.5		46	43	34	9	0.2452	0.2384	
18.5		50	36	34	22	0.2510	0.2460	.014
20.5		54	31	34	35	0.2567	0.2535	
22.5	17	58	27	34	47	0.2623	0.2608	.013
24.5	18	2	24	34	59	0.2679	0.2680	
26.5		6	23	35	12	0.2734	0.2750	.011
28.5		10	24	35	24	0.2789	0.2818	
30.5	18	14	26	+35	37	0.2843	0.2885	.010

EPHEMERIS OF VARIABLES OF THE *ALGOL*-TYPE.

Approximate Greenwich M.T., 1889.

For remarks and comparison-stars, see Vol. VII, p. 187 foll.

September	d	h	September	d	h	September	d	h	September	d	h	October	d	h
U Ophiuchi	1	16	*Y* Cygni	9	16	Algol	16	11	*Y* Cygni	24	16	Algol	3	16
U Ophiuchi	2	13	*U* Cephei	9	17	*S* Cancri	16	23	δ Libræ	25	11	*U* Coronæ	3	16
U Coronæ	2	14	Algol	10	17	*U* Ophiuchi	17	15	*S* Cancri	26	11	*Y* Cygni	3	16
λ Tauri	2	22	λ Tauri	10	20	δ Libræ	18	11	λ Tauri	26	15	*U* Ophiuchi	4	9
U Ophiuchi	3	9	δ Libræ	11	12	*U* Ophiuchi	18	11	*Y* Cygni	27	16	λ Tauri	4	13
Y Cygni	3	16	*U* Ophiuchi	12	14	*Y* Cygni	18	16	*U* Ophiuchi	28	12	*U* Cephei	4	15
δ Libræ	4	12	*Y* Cygni	12	16	λ Tauri	18	17	*R* Canis Maj.	28	13	*S* Cancri	5	22
U Cephei	4	17	*R* Canis Maj.	12	17	*U* Ophiuchi	19	7	*U* Ophiuchi	29	9	Algol	6	12
R Canis Maj.	4	18	*U* Ophiuchi	13	10	*U* Cephei	19	16	*U* Cephei	29	16	*R* Canis Maj.	6	12
R Canis Maj.	5	21	Algol	13	14	*R* Canis Maj.	20	16	*R* Canis Maj.	29	18	*Y* Cygni	6	16
Y Cygni	6	16	*R* Canis Maj.	13	20	*Y* Cygni	21	16	λ Tauri	30	11	*R* Canis Maj.	7	15
U Ophiuchi	6	17	*U* Ophiuchi	14	7	*R* Canis Maj.	21	19	*Y* Cygni	30	16	λ Tauri	8	12
λ Tauri	6	21	*U* Cephei	14	17	*U* Ophiuchi	22	16	*R* Canis Maj.	30	21	*U* Ophiuchi	8	11
U Ophiuchi	7	13	λ Tauri	14	19	λ Tauri	22	16				*R* Canis Maj.	8	19
U Ophiuchi	8	10	*Y* Cygni	15	16	*U* Ophiuchi	23	12	October			Algol	9	9
U Coronæ	9	12	*U* Coronæ	16	9	*U* Cephei	24	16	*U* Ophiuchi	3	13	*U* Ophiuchi	9	10

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OBSERVATIONS OF COMETS,

MADE AT THE U.S. NAVAL OBSERVATORY WITH THE 9.6-INCH EQUATORIAL.

BY PROF. E. FRISBY.

[Communicated by the Superintendent.]

1889 Washington M.T.	*	No. Comp.	☄ — * $\Delta\alpha$	☄ — * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ	Obs.
				COMET *e* 1889.					
d h m s			m s	' "	h m s	° ' "			
Aug. 7 10 10 56.1	1	20 , 4	—4 50.73	—4 47.3	14 58 42.78	+ 5 32 57.8	9.621	0.717	F
8 10 18 34.9	2	20 , 4	—2 57.71	+3 53.9	15 3 45.63	+ 7 7 13.0	9.628	0.711	F
12 10 26 57.8*	3	11 , 3	+3 51.13	—4 49.9	15 21 27.65	+12 25 44.6	9.645	0.688	F
12 10 26 57.8	4	9 , 3	—3 40.27	+2 47.4	15 21 28.64	+12 25 46.2	–	–	F
16 10 18 31.5	5	5 , 1	+0 19.66	+7 6.0	15 36 13.52	+16 30 11.5	9.642	0.654	F
				COMET *e* 1888 †					
Aug. 19 10 5 49.6	6	10 , 2	+0 2.46	—5 50.8	19 3 22.66	— 6 19 36.8	9.057	0.794	F
				COMET *d* 1889.					
Aug. 19 11 26 16.7	7	20 , 4	—2 3.75	+2 31.4	0 8 9.45	— 6 10 22.2	*n*9.489	0.784	F

Mean Places for 1889.0 of Comparison-Stars.

*	α	Red. to app. place.	δ	Red. to app. place	Authority
	h m s	s	° ' "	"	
1	15 3 32.62	+0.91	+ 5 37 10.3	+ 4.8	Grant 3732
2	15 6 42.43	+0.91	+ 7 3 13.7	+ 5.4	Lamont 1657
3	15 17 35.64	+0.88	+12 29 27.1	+ 7.4	Schjellerup 5456
4	15 25 7.99	+0.92	+12 22 51.3	+ 7.5	½(Schjellerup+Grant)
5	15 35 52.87	+0.99	+16 22 59.3	+ 9.2	Grant 3860
6	19 3 18.20	+2.01	— 6 13 54.4	+ 8.4	Weisse's Bessel XVIII, 1584
7	0 10 11.22	+1.98	— 6 13 7.9	+14.3	Weisse's Bessel 0,135

* SCHJELLERUP's right-ascension is probably 1s wrong.

† Some earlier observations of Comet *e* 1888 will appear in the next number of the Journal.

TWO HUNDRED EIGHTY-SEVENTH ASTEROID.

A planet of the tenth magnitude was discovered by **PETERS** at Clinton, N.Y., Aug. 25. Its position was

1889 Aug. 25.5589 Gr. M.T. $\alpha = 22^h\ 15^m\ 17^s.5$, $\delta = -14°\ 3'\ 0''$.

Daily motion, $3^m\ 20^s$ in α, and 10′(?) northward.

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TWO HUNDRED EIGHTY-SEVENTH ASTEROID.

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No. 202.

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ON PHOTOGRAPHING AND SEEING STARS IN THE DAY-TIME.

BY EDWARD S. HOLDEN.

The following is an elementary theory of the subject of photographing a star projected against a bright background.

Let J be the intrinsic brilliancy of a planet,
" I " " " " star,
" i " " " " the sky,
" a " aperture of a telescope,
" f " focal length of a telescope,
" t " percentage of the incident light transmitted by the objective,
" K " intrinsic brilliancy of the image of a planet formed in the focus f,
" L " same for a star,
" i " " the sky,
then

$$(1)\quad K = J \,.\, t \,.\, \frac{a^2}{f^2}\,; \qquad (2)\quad k = i \,.\, t \,.\, \frac{a^2}{f^2}\,.$$

In the usual simple theory of vision by telescopic aids, the image of a star is assumed to be a point, and

$$(3)\qquad L = a^2 \,.\, t \,.\, I.$$

However it may be for visual images of stars, it is certain that their photographic images are discs and not points, and that

L is less than $a^2 \,.\, t \,.\, I$, and also that
L is greater than $\frac{a^2}{f^2} \,.\, t \,.\, I$.

I shall assume, with Professor PICKERING (*Mem. Amer. Acad.* Vol. XI, page 188), that the law is very approximately given by the following equation,

$$(4)\qquad L = \frac{a}{\sqrt{f}} \,.\, t \,.\, I\,.\,,$$

when we consider the photographic image of a star. This equation may not be rigorous, and the coefficient $\frac{a}{\sqrt{f}}$ may require a change, but we know enough already to be sure that the change will not be great.

From (2) and (4) it follows:

$$(5)\qquad \frac{L}{k} = \frac{f^{\frac{3}{2}} \,.\, I}{a \,.\, i}\,.$$

This expression gives the ratio of the intrinsic brilliancies of the images of a star and its background as photographed in any telescope, always assuming that the plate and the exposure-time are constant. It shows that there may be great advantages, in the photography of a star against a bright background, in the use of a telescope whose focus is relatively long compared to its aperture. Let us compare the operation of a portrait lens, $a = 5$, $f = 30$ inches, with that of the Lick telescope, $a = 33$, $f = 570$ inches. Let us suppose t to be the same for both instruments, and equal to 1, and also that the star is ten times as bright as its background, or $I = 10\, i$. This is about the ratio of brilliancy of the polar rays of the corona of January 1889 to their background.

TABLE I.

	Portrait lens	Lick Telescope
Brilliancy of the image of the sky	0.03 i	0.003 i
" " " star	9.13 i	13.82 i
Contrast (image of the star brighter than that of the sky)	329 to 1	1121 to 1

The advantage of using the Lick telescope in this case is manifest. It is chiefly due to the large value of the ratio $\frac{f}{a}$ for this telescope, and not to the great size of the objective. It will be noticed that the brightness of the star image is only a little greater in the larger instrument (as 14 to 9); but the brightness of the image of the sky is much less (as 1 to 10), and hence the contrast is much greater in the longer focused lens.

Let us see what would have been the result of cutting down the aperture of the portrait lens to 1 inch, leaving everything else unchanged.

TABLE II.

	Portrait Lens	
	Full aperture	Aperture 1 inch
Brilliancy of the image of the sky	0.03 i	0.001 i
" " " star	9.13 i	1.83 i
Contrast	329 to 1	1643 to 1

It is thus plain that a small photographic contrast, such as sky and star, can be increased with a given telescope by simply cutting down the aperture. This enfeebles the light of the star (as 9 to 2 in Table II), but it enfeebles the light of the sky vastly more (as 30 to 1 in Table II), and thus produces the contrast which is necessary.

It is clear that we can calculate beforehand just what aperture must be chosen to produce a given contrast — such a one as we know beforehand that we are able to photograph. We must then choose a suitable exposure. Theoretically, we should always profit by employing a long-focused lens to photograph a star projected on a bright sky, just as we theoretically always gain in seeing a star so projected by using a high magnifying power; and for a similar reason — namely, the consequent great relative darkening of the background. Practically, however, we may not gain by pushing the contraction of the aperture too far, as the light of the star is enfeebled absolutely (about 5 times in Table II), and thus the necessary exposure is unduly lengthened.

Application to the Case of Stars Seen in the Day-time.

To a certain extent the foregoing simple theory is applicable to vision, as well as to photography. The visual images of stars are not points, although they are nearly so. Equation (4) fits the case of photography better than that of vision, but the expression is approximately true for stars seen in the day-time projected on a bright background.

As the star is *nearly* a point, we can gain something by using a high magnifying power, though not so much as is commonly assumed; as the star is not absolutely a point, we can see it better in the day-time, *as contrasted with its background*, by cutting down the aperture to $\frac{3}{4}$ or $\frac{1}{2}$ of its usual amount. I have convinced myself that this is so by trial; and Mr. Barnard also tells me that at Nashville it was his practice to reduce the aperture of his transit instrument, in order to see stars better in the day-time.

This deduction is worth the attention of observers with meridian-circles who are observing stars in the day-time, as it will save them many days otherwise lost. For example, with the large transit-circle at Washington, there are many days when the sun is observed, but when the necessary fundamental stars cannot be seen, on account of the brightness of the sky. If the aperture is reduced to about $\frac{3}{4}$ or $\frac{1}{2}$, the darkening of the background will be sufficient to permit the observation of these stars, and thus much will be saved. I believe this simple result to be quite new. In practice it is almost exactly true for photography, and it is approximately true for vision.

Lick Observatory, 1889 *August* 1.

SOME OBSERVED MAXIMA AND MINIMA OF LONG-PERIOD VARIABLES IN 1889,

BY P. S. YENDELL.

R Virginis.

A series of nine observations of this star, from May 6 to June 19, indicate a maximum on June 2. The observations were much interrupted by unfavorable weather, but are sufficient to indicate the maximum phase with considerable distinctness.

T Cephei.

A good series of telescopic and field-glass observations, numbering in all thirty-seven, were obtained from April 22 to July 5. Only enough of the light-curve was observed to show that it was markedly flat at the maximum, remaining at the greatest light, which was about 6^{M}, from May 11 to June 16; a maximum is indicated on May 29.

T Herculis.

Observations of *T Herculis* were begun April 28, when the star's light was estimated at about $9^{M}.5$, it increased steadily and rapidly, and a maximum of $7^{M}.8$ was passed May 24, after which it declined rather less rapidly than it had increased, until the last observation on June 24, when it had reached $9^{M}.2$. Nineteen observations were made.

T Serpentis.

This star when first seen on June 20, was estimated to be $9^{M}.5$. Only five observations in all were obtained, but these indicate with sufficient definiteness that a maximum was passed on June 24, when the star's light was about $9^{M}.2$; the rise and decline were sharp and well-marked; at the last observation, on July 6, its magnitude was about $9^{M}.7$.

V Ophiuchi.

Thirteen observations of *V Ophiuchi* were secured from May 26 to July 25. A maximum is indicated on June 1. The rise from its brightness at the first observation to the maximum, which occurred but six days later, was only about 2.5 steps, or $0^{M}.25$, and its decline was slow and irregular, having fallen when last observed only 7 steps, or $0^{M}.7$ from its greatest light, which was by eye-estimation about $7^{M}.5$.

Dorchester, 1889 *August* 3.

OBSERVATIONS OF *70 OPHIUCHI*,

MADE AT THE U.S. NAVAL OBSERVATORY,

BY A. HALL.

[Communicated by the Superintendent.]

Date	p	s	Date	p	s	Date	p	s	Date	p	s
1880.515	65.9	2.72	1883.573	49.1	2.40	1886.516	14.4	1.94	1888.545	352.5	2.11
.572	67.2	2.79	.581	47.7	2.19	.522	14.2	2.05	.556	353.8	2.00
.575	64.3	2.77	.592	46.5	2.45	.525	14.6	1.96	.562	353.3	2.05
.581	65.7	2.88	.598	47.5	2.37	.530	12.3	2.01	.570	353.7	1.95
.583	65.5	2.68	.601	48.6	2.21	.541	11.0	1.98	.586	352.7	2.05
.603	64.2	2.64	.603	48.2	2.16	.544	14.3	1.94	.589	351.9	1.98
1880.576	65.47	2.747	.612	46.8	2.20	.552	12.6	2.02	1888.568	353.45	2.020
			.628	47.8	2.18	1886.533	13.77	1.986			
			1883.598	47.77	2.270						
						1887.565	2.4	1.89	1889.515	344.9	2.07
1881.512	61.0	2.67	1884.548	38.7	2.20	.590	1.7	1.98	.523	344.7	2.16
.522	62.3	2.40	.581	37.9	2.23	.595	4.9	1.93	.567	344.5	2.10
.531	60.6	2.46	.597	36.7	2.00	.625	4.2	1.92	.605	345.6	2.03
.536	60.2	2.46	.600	37.7	2.13	.634	3.0	1.82	.616	343.1	2.12
.588	59.2	2.49	.605	37.5	2.16	.680	2.3	1.98	.630	344.3	2.10
1881.538	60.66	2.496	.614	37.2	2.26	1887.615	3.58	1.920	1889.576	344.52	2.097
			.616	37.5	2.18						
			1884.594	37.60	2.166						
1882.519	53.1	2.25	1885.553	29.0	1.93						
.533	57.9	2.29	.561	28.6	1.93						
.560	56.5	2.45	.561	28.2	1.87						
.566	57.2	2.29	.566	29.2	1.95						
.571	57.5	2.32	.575	30.5	1.81						
.609	56.8	2.26	.580	31.0	1.79						
.648	53.8	2.30	.599	30.3	1.88						
1882.572	56.16	2.309	1885.571	29.54	1.880						

The first observation of this interesting star is by HERSCHEL in 1779, and the observations extend over more than a revolution, which is about ninety-five years. It appears, however, that there is still an indetermination in some of the elements, and the preceding measurements, made near the periastre of the stars, may be of use in helping to remove this uncertainty in determining the orbit. Each of these observations is the result of four settings of the position-circle, and of two measures of the double distance

Naval Observatory, 1889 *August* 19.

OBSERVATIONS OF ENCKE'S COMET, *PROSERPINA* AND *NIOBE*, MADE AT CORDOBA IN 1888,

BY JOHN M. THOME.

ENCKE'S COMET.

1888 C.M.T.				⁎	No. Obs.	☄ — ⁎		☄'s apparent			
	h	m	s			Δα	Δδ	App. α	log pΔ	App. δ	log pΔ
July 28	7	23	56.9	1	7	−1 25.59	−6 53.19	11 23 53.96	n9.674	−10 57 56.30	n0.596
29	7	25	38.9	2	6	+0 11.65	−2 35.91	11 32 18.31	n9.673	12 9 2.8	n0.581
30	7	22	11.1	3	8	−2 20.11	−6 37.94	11 40 13.19	n9.670	13 18 58.50	n0.570
31	7	16	33.2	4	5	−3 38.56	+2 23.98	11 49 11.62	n9.662	14 27 12.79	n0.550
Aug. 1	7	26	53.6	5	5	+4 3.11	−8 12.31	11 57 15.37	n9.670	15 34 27.66	n0.515
3	7	16	14.4	6	4	−1 17.68	+5 13.63	12 11 17.51	n9.653	17 11 35.75	n0.500
5	7	17	25.4	7	14	−0 3.50	−9 25.01	12 31 50.66	n9.649	19 40 48.17	n0.463
23	7	21	33.0	8	3	+3 1.63	−1 36.80	14 48 55.70	n9.581	30 8 31.5	n0.039
24	7	23	49.7	9	5	+2 29.46	−7 52.78	14 55 14.16	n9.582	30 23 40.5	n0.025
25	7	18	41.7	10	6	+1 36 28	−8 21.15	15 1 22.76	n9.566	−30 37 23.4	n9.980

NOTES: — July 28, dense haze. July 31, dense haze. Aug. 1, clouds, observations interrupted. Aug. 2, clouds, observations broken off. Aug. 23, comet very faint. Aug. 24, comet very faint. Aug. 25, comet barely visible.

Mean Places for 1888.0 of Comparison-Stars.

Comp.	Star	Mag.	α	Red.	δ	Red.	Authority
			h m s	s	° ′ ″	″	
1	S. DM. 3282	9¾	11 25 19.50	+0.05	—10 50 58.95	—4.64	Cordoba M.C.
2	" 3137	10	11 31 32.62	0.07	12 6 22.3	4.81	Comp. with W.B. 439
3	W.B. 716	9¼	11 43 3.17	0.11	13 12 16.01	4.93	Cordoba M.C.
4	" 788	8	11 52 50.02	0.16	11 29 31.77	5.12	" "
5	" 890	8¼	11 53 41.79	0.16	15 25 40.53	5.29	" "
6	OA. 12112	8¾	12 16 4.92	0.27	17 46 43.97	5.65	" "
7	" 12294	9¼	12 31 53.81	0.35	19 31 17.65	5.91	" "
8	A.G.C. 20135	6¾	14 45 53.10	0.97	30 6 52.0	5.80	Arg. Gen. Cat.
9	" 20313	7	14 52 44.01	0.99	30 15 42.4	5.61	" "
10	" 20484	6½	14 59 45.46	+1.02	—30 28 57.1	—5.42	" "

PROSERPINA (26).

1888 C.M.T.	*	No. Obs.	(26) — * Δα	(26) — * Δδ	App. α	log pΔ	App. δ	log pΔ
h m s			m s	′ ″	h m s		° ′ ″	
June 15 7 58 36.0	1	10	—1 7.15	+11 14.9	17 32 44.24	9.685	—27 8 41.6	*n*0.361
20 10 40 3.1	2	8	—2 22.02	— 9 32.3	27 44.27	9.092	11 4.9	*n*9.851
26 9 7 35.7	3	11	—1 24.04	— 5 11.7	22 11.88	9.429	11 58.4	*n*0.016
27 7 38 12.9	3	10	—2 14.01	— 5 8.8	21 21.90	9.633	11 55.7	*n*0.261
28 7 26 31.2	3	7	—3 5.63	— 5 0.4	20 30.28	9.614	11 47.4	*n*0.280
July 1 7 20 15.5	4	5	+1 9.28	+ 7 57.4	18 0.23	9.619	11 11.2	*n*0.240
2 8 8 22.9	4	10	—0 20.55	+ 8 13.2	17 11.49	9.520	10 55.4	*n*0.109
3 7 10 56.5	4	10	—0 23.63	+ 8 29.2	16 27.31	9.631	10 39.4	*n*0.269
4 7 15 34.2	4	10	—1 8.71	+ 8 52.8	15 42.20	9.615	10 15.8	*n*0.233
5 7 19 22.8	5	11	+0 51.50	+ 8 22.5	14 58.86	9.599	9 49.5	*n*0.210
7 7 18 12.1	5	10	—0 31.03	+ 9 17.2	13 36.33	9.583	8 54.9	*n*0.187
8 7 12 50.2	5	6	—1 9.72	+ 9 42.5	12 57.64	9.584	8 29.6	*n*0.190
8 7 25 13.4	6	6	—0 59.38	+ 5 14.5	17 12 57.49	9.557	—27 8 24.2	*n*0.154

NOTES: — June 15, through clouds, not good. July 1, clouds. July 8IId, very faint.

Mean Places for 1888.0 of Comparison-Stars.

Comp.	Star	Mag.	α	Red.	δ	Red.	Authority
			h m s	s	° ′ ″	″	
1	A.G.C. 23949	8¼	17 33 51.23	+2.16	—27 20 0.5	+4.0	Arg. Gen. Cat.
2	ZC. 1981	8¾	30 4.09	2.20	1 36.3	3.7	Cordoba M.C.
3	" 1542	9¼	23 33.63	2.27	6 49.9	3.1	" "
4	" 1085	9	16 48.68	2.27	19 11.0	2.4	" "
5	A.G.C. 23475	7½	14 5.08	2.27	18 14.2	2.2	Arg. Gen. Cat.
6	ZC. 897	8	17 13 54.59	+2.28	—27 13 40.8	+2.1	Cordoba M.C.

NIOBE (71).

1888 C.M.T.	*	No. Comp.	(71) — * Δα	(71) — * Δδ	App. α	log pΔ	App. δ	log pΔ
h m s			m s	′ ″	h m s		° ′ ″	
July 10 9 40 13.0	1	10	+2 11.74	— 9 5.59	19 48 27.14	9.643	—39 1 22.6	*n*8.799
13 10 33 46.6	1	3	—2 0.63	+10 43.23	44 14.80	9.439	38 41 32.4	9.842
14 8 25 24.0	2	10	—1 30.95	+ 5 43.76	42 59.68	9.723	38 35 4.5	*n*9.948
16 8 15 25.3	3	10	—0 55.44	— 4 21.36	40 16.77	9.722	38 20 20.3	*n*9.965
17 8 20 4.8	4	9	—1 53.68	— 5 23.66	38 54.97	9.712	38 12 34.6	*n*9.914
20 7 45 0.4	5	11	—1 11.74	— 0 35.24	34 59.64	9.735	37 48 31.5	*n*0.075
21 7 45 20.7	6	5	—1 47.40	+ 1 52.40	33 41.85	9.727	37 40 0.3	*n*0.045
22 8 38 25.4	7	10	—0 15.72	+ 8 7.11	32 22.77	9.611	37 31 3.8	*n*9.368
25 8 9 16.2	8	8	+2 13.34	+ 1 57.53	28 42.18	9.655	37 4 6.1	*n*9.681
8 23 21.0	9	8	+0 9.24	— 1 12.20	28 41.27	9.628	37 4 0.8	*n*9.454
27 10 3 50.8	10	9	—2 11.98	— 4 34.70	19 26 15.59	9.195	—36 44 27.7	9.847

NOTES: — July 13, through clouds, poor. July 14, dense haze. July 25, clouds and wind. July 27, very faint.

Mean Places for 1888.0 of Comparison-Stars.

Comp.	Star	Mag.	α	Red.	δ	Red.	Authority
			h m s	s	° ′ ″	″	
1	ZC. 1897	9	19 46 12.81	+2.59	—38 52 27.81	+10.85	Cordoba M.C.
2	Anon.	8¾	19 44 28.00	2.63	38 41 8.51	10.38	" "
3	ZC. 1711	8½	19 41 9.57	2.61	38 16 8.76	9.91	" "
4	A.G.C. 27093	7¾	19 40 45.99	2.65	38 7 20.8	9.83	Arg. Gen. Cat.
5	" 26987	6	19 36 8.68	2.69	37 48 5.6	9.35	" "
6	" 26971	7¼	19 35 26.54	2.71	37 42 1.9	9.24	" "
7	" 26896	8	19 32 35.77	2.72	37 39 19.8	8.93	" "
8	" 26775	9	19 26 26.11	2.73	37 6 11.8	8.16	" "
9	" 26813	7½	19 28 29.30	2.73	37 2 56.9	8.30	" "
10	ZC. 1177	9½	19 28 28.45	+2.72	—36 40 1.09	+ 8.08	Cordoba M.C.

OBSERVATIONS OF COMET *e* 1888,

MADE AT THE U.S. NAVAL OBSERVATORY WITH THE 9.6-INCH EQUATORIAL.

BY PROF. E. FRISBY.

[Communicated by the Superintendent.]

1889 Washington M.T.	*	No. Comp.	☄ — * Δα	☄ — * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ	Obs.
d h m s			m s	′ ″	h m s	° ′ ″			
July 25 11 56 14.7	1	20 , 4	+0 11.44	— 1 17.3	20 15 52.14	—2 22 56.1	*n*7.819	0.761	F
27 10 6 57.9	2	20 , 4	—0 50.11	+10 11.4	20 9 7.55	—2 43 51.5	*n*9.272	0.771	F

Mean Places for 1889.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	20 15 38.59	+2.11	—2 21 47.8	+9.0	½(Lamont + Weisse)
2	20 9 55.85	+2.11	—2 51 11.9	+9.0	⅓(Weisse + 2 Schjellerup)

Correction to observation of July 8 (p. 55): For mean time $13^{h}\,21^{m}\,15^{s}.0$, read $13^{h}\,31^{m}\,11^{s}.0$.

ON THE COMPANIONS TO COMET *d* 1889 (*BROOKS*),

BY E. E. BARNARD, ASTRONOMER OF THE LICK OBSERVATORY.

Since the discovery of a group of companions to the great comet of 1882 (see *A.N.* 2489), I have been impressed with the idea that other comets may be attended by companions which, from their faintness, or from a failure to search for them, may escape discovery. I have therefore examined the immediate neighborhood of all comets since then in the hope of finding such companions.

The 12-inch telescope being out of order, it was not possible to observe BROOKS's comet with it after the July moon until the night of August 1, when I observed the comet for position. While examining the region about the head of the comet on this date, I detected two small nebulous bodies following the head, but preceding the comet in space. The nearest of these was suspected to be a companion; its distance and position-angle were therefore measured from the nucleus. The second morning showed that both objects were moving with the comet, and therefore were companions. These objects I have named *B* and *C*.

On August 3, these were examined with the 36-inch equatorial, which showed the whole group very beautifully. Each of the companions had a very small nucleus and condensation in a very small head, and a short, faint tail, presenting a perfect miniature of the larger one, which was pretty bright and well developed, with small nucleus and slightly fan-shaped tail ¼′ long. There was then absolutely no nebulous connection with the larger, nor has there been at any time since, either in the 12-inch or in the 36-inch telescopes. Nothing whatever has been seen here of the nebulous envelope spoken of by the Vienna observers as apparently enclosing the whole group (*A.N.* 2914). I have from the first carefully looked for a nebulous connection. Under unfavorable circumstances the tails of *B* and *C* might be imagined to be a connecting nebulosity, but the tail of *B* falls short of *A*, and that of *C* does not nearly reach *B*. Each comet is in appearance absolutely independent of the other. The tails of all three have lain in the line of the nucleus of *A*, and therefore have not sensibly deviated from the position-angle 241°.

On August 4, two other companions were detected with the great telescope, one of which was measured, the other being too elusive to place the wires on. I have numbered these four companions *B*, *C*, *D*, *E*, in the order of increasing right-ascension, *A* being the larger comet, *D* and *E* being the two last discovered. The position of *D* Aug. 4, referred to *C* was: distance, 78″.18; P.A., 23°.3. *D* has been seen several times since the moon withdrew, but has always been too faint to observe; it has not sensibly changed its position. *E* has only been seen once; its position-angle referred to *C* would be the same as that of *D*, and its distance twice as great. Four or five other nebulous bodies observed near the comet August 2 have not since been seen, and were probably nebulous.

The results of the observations of the two brighter companions are extremely interesting. Measures of *B* have been made on eighteen and of *C* on seventeen nights. These two have almost exactly the same position-angles, which have been sensibly constant; their distances from the main body have, however, been increasing. At the last few observations, *B* seems to be stationary, the distance from *A* remaining constant, while *C* continues to recede. The following from my measurements will give some idea of these changes.

From Aug. 1 to Aug. 5, *B* was separating from *A* at the mean rate of 0″.93 per day, while from Aug. 16 to Aug. 24 this was reduced to 0″.20, or essentially zero.

From Aug. 2 to Aug. 5 *C* was receding 1″.72 per day, and from Aug. 16 to Aug. 21 this had increased to 2″.76.

From Aug. 1 to Aug. 5 the mean position-angle *AB* was 59°.92, and from August 16 to 24 it was 61°.27.

Aug. 3 to Aug. 5 the mean position-angle *AC* was 61°.43; and from Aug. 16 to Aug. 21, 61°.68. At first the position-angle *AB* was sensibly less than *AC*. They now appear to be on the same line with the nucleus.

Following are the positions of the two companions with reference to the nucleus *A* on two of the dates of observation:

Aug. 3	*AB*	66″.18	59°.9	:	*AC*	263″.46	61.4
Aug. 28	*AB*	73.22	63.2	:	*AC*	328.41	61.6

I have measured these objects every night, except when the moon interfered, and have been struck with the rather sudden change in the appearance of *B*. At first very small, with ill-defined nucleus, and a tail nearly 1′ long, it was comparatively an easy object to measure in the 12-inch. It has steadily become more difficult, even in the great telescope, and at the last few observations has become extremely difficult, ceasing to be visible in the 12-inch; the central condensation has disappeared almost entirely, and the nebulosity become much larger, fainter, and more diffused, making it almost impossible to bisect it accurately. In the mean time *C* has become easier, perceptibly brightening, and the central condensation more marked.

Since August 2, the observations have been made with the 36-inch equatorial.

In hopes that it may be possible to determine the mass o this cometary system, I have made careful micrometric measures on every night possible, and these measures will be kep up as long as the companions can be seen.

Mt. Hamilton, 1889 *August* 29.

RING-MICROMETER OBSERVATIONS OF COMET *e* 1889 (*DAVIDSON*).

MADE AT THE LEHIGH UNIVERSITY OBSERVATORY.

BY C. L. DOOLITTLE.

1889 Greenwich M.T.	✻	No. Comp.	☄ — ✻		☄'s apparent		log pΔ	
			Δα	Δδ	α	δ	for α	for δ
d h m s			m s	′ ″	h m s	° ′ ″		
Aug. 18 13 33 42.7	*a*	7	+0 30.37	— 2 32.3	15 42 33.09	+18 7 19.1	9.482	0.614
26 13 49 57.5	*b*	5	+3 11.32	+ 1 38.8	16 4 58.46	+23 12 32.2	9.548	0.536
27 13 51 34.2	*c*	10	+0 32.59	— 4 57.3	16 7 27.93	+23 12 9.9	9.555	0.532
28 13 8 49.6	*d*	6	—3 20.99	+16 28.8	16 9 48.85	+24 9 20.4	9.469	0.480
29 13 13 51.0	*e*	6	+1 44.24	—12 35.7	16 12 12.27	+24 36 1.5	9.587	0.540
30 13 46 25.0	*f*	6	—1 39.40	—12 33.7	16 14 35.01	+25 1 45.4	9.528	0.493
31 14 10 39.5	*f*	6	+0 39.72	+12 2.7	16 16 54.11	+25 26 21.8	9.601	0.538

Mean Places for 1889.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place.	Authority
	h m s	s	° ′ ″	″	
a	15 12 1.86	+0.86	+18 9 41.5	+ 9.9	Ring-micro. comp. with W.B. 15.985
b	16 1 16.34	+0.80	+23 10 41.6	+11.8	Weisse's Bessel 15.1518
c	16 6 51.53	+0.81	+23 46 55.1	+12.1	" " 16.155
d	16 13 9.02	+0.82	+23 52 39.3	+12.3	" " 16.351
e	16 19 27.26	+0.77	+24 18 24.7	+12.5	" " 16.271
f	16 16 13.63	+0.78	+25 14 6.3	+12.8	" " 16.429
		+0.76		+12.8	

Bethlehem, Pa., 1889 *Sept.* 2.

ELEMENTS OF COMET *e* 1889 (*DAVIDSON*),

By T. H. SAFFORD.

The following elements of Comet *e* 1889 were obtained from the observations at Rome July 26, and at Washington Aug. 7 and Aug. 16. The small corrections were taken into account, and the logarithm of M was varied so as to produce a close accordance.

$$T = 1889 \text{ July } 19.3066 \text{ Gr. M.T.}$$
$$\log q = 0.016959$$
$$\left.\begin{aligned}\omega &= 345^\circ\ 53'\ 59''.0\\ \Omega &= 286\ \ \ 8\ \ 21\ .3\\ i &= \ 65\ \ 59\ \ 16\ .1\end{aligned}\right\}\ 1889.0$$

Winthrop Beach, Mass., 1889 *August* 28.

The middle observation was thus represented:

$$(\text{C}-\text{O}),\ \Delta\lambda,\ -11''.1\ ;\ \Delta\beta,\ +5''.2.$$

By a trifling change I could have represented the latitude rather better, but not the longitude. It will thus appear that the rather large discrepancies which both Mr. Bellamy and myself found in the first sketch of the orbit did not arise from ellipticity, if we take the observations here employed as correct.

ELLIPTIC ELEMENTS AND EPHEMERIS OF COMET *d* 1889.

By Rev. GEORGE M. SEARLE.

I have computed the following elements of comet *d* 1889 from the observations at Mt. Hamilton, July 8; Cambridge, July 23; and Washington, Aug. 19.

$$T = 1889 \text{ Sept. } 11.0324 \text{ Gr. M.T.}$$
$$\left.\begin{aligned}\Omega &= \ 19^\circ\ 23'\ 29''\\ \omega &= 335\ \ \ 9\ \ 20\\ i &= \ \ \ 5\ \ 59\ \ 53\end{aligned}\right\}\ 1889.0$$
$$\varphi = \ 30\ \ 50\ \ 51$$
$$\log q = 0.301773$$
$$\log a = 0.614037$$

Period = 8.34 years.

Middle place, (O—C), $\Delta\lambda = -25''$, $\Delta\beta = -2''$.

The discordance in λ is owing to the computation being made from the first hypothesis for the ratio of the triangles, which was taken from the previous orbit. The ellipticity in this case shows itself principally in latitude.

These furnish the following equations for the equatorial coordinates for 1889.0.

$$\begin{aligned}x &= [0.613240]\ \sin\,[E+85\ 13\ 18'']-2.09727\\ y &= [0.489679]\ \sin\,[E-\ 5\ 10\ 23]+\ \ .11277\\ z &= [0.237690]\ \sin\,[E-10\ 35\ 12]+\ \ .10284\end{aligned}$$

and the following ephemeris for Greenwich midnight.

1889	α	δ	log Δ	Br.
	h m s	° ′		
Sept. 12	23 59 13	—5 38.7	0.0017	1.81
16	57 22	33.7	0.0007	
20	54 56	27.7	0.0011	
24	52 29	20.6	[illegible]	
28	23 50 9	—5 12.0	0.0067	1.76

The unit of brightness is that of the observation of July 8.

ELLIPTIC ELEMENTS OF COMET *d* 1889, WITH EPHEMERIS.

By S. C. CHANDLER.

The surmise which I expressed on page 56 of this Journal, that this comet would prove to be one of short period, appears to be verified. Thus, from the observations at the Lick Observatory on July 8, at Dresden and [illegible] July 31, and at Washington August 19, I find the elliptic elements following:

$$\begin{aligned} T &= 1889 \text{ Sept. } 15.3618 \text{ Gr. M.T.} \\ \omega &= 335^\circ\ 50'\ 42'' \\ \Omega &= 19\ \ 15\ \ \ 8 \\ i &= 6\ \ \ 0\ \ 10 \end{aligned} \Bigg\} 1889.0$$

$$\log q = 0.300652$$

$$e = 0.507112$$

The corresponding period is 2990 days, or 8.186 years.

EPHEMERIS FOR GREENWICH MEAN TIME.

1889	App. α h m s	App. δ ° ′	log r	log Δ	Br.
Sept. 18.5	23 56 3	—5 30.9	0.3007	9.9983	2.31
20.5	54 48	5 27.8			
22.5	53 35	5 24.4	0.3009	9.9995	2.30
24.5	52 22	5 20.7			
26.5	51 12	5 16.6	0.3012	0.0022	2.27
Sept. 28.5	23 50 2	—5 12.1			
Sept. 30.5	23 48 53	—5 7.2	0.3016	0.0065	2.22
Oct. 2.5	47 49	5 1.8			
4.5	46 50	4 56.0	0.3021	0.0122	2.15
6.5	45 54	4 49.6			
8.5	45 4	4 42.8	0.3028	0.0193	2.08
10.5	44 18	4 35.4			
12.5	43 38	4 27.5	0.3036	0.0276	1.99
14.5	43 4	4 19.2			
Oct. 16.5	23 42 36	—4 10.2	0.3046	0.0371	1.90

EQUATORIAL COORDINATES; MEAN EQUINOX 1889.0.

$$\begin{aligned} x &= r\,[9.999712]\,\sin[\ 84^\circ\ 59'\ 58''+v] \\ y &= r\,[9.941381]\,\sin[356\ \ 6\ \ \ 0+v] \\ z &= r\,[9.688078]\,\sin[351\ 27\ 28+v] \end{aligned}$$

OBSERVATIONS OF THE OCCULTATION OF *JUPITER* BY THE MOON, 1889 SEPTEMBER 3,

MADE AT THE UNITED STATES NAVAL OBSERVATORY,

[Communicated by the Superintendent.]

Phase	Object	Washington Sidereal Times h m s	Observer	Remarks
Immersion	Third Satellite	20 25 9.2	H	Fair observation
"	Second Satellite	20 27 50.3	H	Very doubtful, clouds
"	*Jupiter*, 2d Limb	20 37 28.9	S	Contact well observed
"	" "	20 37 34.9	H	Good
"	First Satellite	20 37 56.8	H	Good
Emersion	Second Satellite?	21 20 7.2	H	Uncertain

Observers: — A. HALL, 26-inch equatorial, power 383. A. N. SKINNER, 9.6 equatorial, power 132.

The sky was cloudy most of the time. The disappearance of the Third Satellite was gradual, lasting about three seconds.

Naval Observatory, 1889 *September* 5.

ADVERTISEMENT.

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OBSERVATIONS OF VARIABLES OF THE *ALGOL*-TYPE,

BY P. S. YENDELL.

During the present year the writer has made special efforts to secure as many observations as possible of the minima of variables of this class. There have been obtained one of *U Cephei*, two of *δ Librae*, two of *U Coronae*, and eight of *U Ophiuchi*, besides several partial series of observations from which other minima may be deduced with the aid of mean light-curves. The number of observed minima has been restricted by unfavorable weather, and by the fact that observations after midnight were, in general, impracticable. For these reasons no minima have been secured of *λ Tauri*, *S Cancri*, or *R Canis Majoris*: but it is intended in the future to include in the program all known objects of this class.

The times of minimum were in every case first deduced by means of single curve drawings, formed from the observations of each evening. This seems to me to be the best way under ordinary circumstances, where a fair number of comparisons have been obtained before and after minimum. But it has also been thought well to determine the times of minima by means of some standard light-curve, where such was available; and, besides, to give the result which would be derived from taking the middle times of equal brightness before and after minimum, for various points during decrease and increase. It will be useful to give the results of these various methods, for the purpose of comparison, and with all necessary detail, below. Cambridge mean time is used in all cases.

U Cephei.

The minimum of 1888 Oct. 10 has been published already (*A.J.*, IX, 22), but is repeated here for the sake of giving the results by the other methods of reduction. The mean light-curve used is that of Mr. CHANDLER (p. 52).

1888 Oct. 10; nineteen observations, from $7^h 30^m$ to $13^h 5^m$.

Time of minimum by single curve, $11^h 18^m.1$, wt. 5.

Time of minimum by mean light-curve (autumn), $11^h 13^m.1$.

Times of equal brightness,

	Before	After	Middle
M	h m	h m	h m
8.3	9 13.4	13 2.4	11 7.9
8.6	9 54.9	12 49.9	11 22.4
8.9	10 17.4	12 31.4	11 24.4
Mean of middle times			11 18.2

1889 May 5; eleven observations, from $8^h 30^m$ to $10^h 30^m$.

Time of minimum by single curve, $9^h 16^m.5$, wt. 1.

Time of minimum by mean light-curve (spring), $9^h 15^m.0$.

Times of equal brightness,

	Before	After	Middle
M	h m	h m	h m
8.9	8 36.0	9 50.0	9 13.0

The observations of this star and the following, *U Coronae*, were all made with the $4\frac{1}{4}$-inch refractor.

U Coronae.

The mean light-curve used in the following reductions of the observations of this star is that published by WINNECKE in the *Astronomische Nachrichten*.

1889 May 18; eight observations, from $8^h 35^m$ to $10^h 15^m$.

Time of minimum by single curve, $9^h 18^m.0$, wt. 2.

Time of minimum by mean light-curve, $9^h 19^m.5$.

Times of equal brightness,

	Before	After	Middle
M	h m	h m	h m
8.9	8 51.5	9 44.5	9 18.0
9.0	9 6.5	9 33.5	9 20.0
Mean of middle times			9 19.0

1889 June 18; eleven observations, from $9^h 3^m$ to $11^h 5^m$. Sky hazy, at times very much so.

Time of minimum by single curve, $10^h 22^m.6$.

Time of minimum by mean light-curve, $10^h 19^m.3$.

Times of equal brightness,

	Before	After	Middle
M	h m	h m	h m
8.7	9 1.1	11 39.6	10 20.4
8.8	9 27.6	11 6.6	10 17.1
8.9	9 42.1	10 53.6	10 17.8
9.0	10 17.1	10 32.6	10 24.8
Mean of middle times			10 20.0

δ Librae.

The observations of this star were made with an opera-glass of seventeen lines aperture and magnifying power of two. Owing to the star's position, but little of the rising curve could be obtained in either case. The mean light-curve used in the reductions is that of Schönfeld (*A. N.*, 74, 347).

1889 July 17: ten observations, from $8^{h}\ 15^{m}$ to $11^{h}\ 10^{m}$. The star was followed until it was too low for a fair comparison to be obtained.

Time of minimum by single curve, $10^{h}\ 12^{m}.4$, wt. 4.

Time of minimum by mean light-curve, $10^{h}\ 6^{m}.5$.

Times of equal brightness,

	Before	After	Middle
M	h m	h m	h m
5.9	9 18.9	10 56.9	10 7.9
6.0	9 31.9	10 47.9	10 9.9
6.1	9 48.9	10 28.9	10 8.9
Mean of middle times			10 8.9

1889 July 24; nine observations, from $8^{h}\ 40^{m}$ to $11^{h}\ 0^{m}$. Observed as before, until too low.

Time of minimum by single curve, $10^{h}\ 26^{m}.7$, wt. 3.

Time of minimum by mean light-curve, $10^{h}\ 13^{m}.1$.

Times of equal brightness,

	Before	After	Middle
M	h m	h m	h m
6.0	9 42.5	10 56.0	10 19.2
6.1	10 6.5	10 43.5	10 25.0
Mean of middle times			10 22.1

U Ophiuchi.

In the case of this star the substantial coincidence of my own light-scale with Chandler's has greatly facilitated the use of his mean light-curve, in Vol. VII, p. 138. The observations were mostly made with the opera-glass, aided occasionally by the field-glass.

1889 May 26: five observations, from $9^{h}\ 5^{m}$ to $10^{h}\ 30^{m}$.

Time of minimum by single curve, $9^{h}\ 26^{m}.5$, wt. 2.

Time of minimum by mean light-curve, $9^{h}\ 29^{m}.2$.

Times of equal brightness,

	Before	After	Middle
M	h m	h m	h m
6.6	9 9.0	9 42.5	9 25.7

1889 May 31; eight observations, from $9^{h}\ 0^{m}$ to $10^{h}\ 45^{m}$.

Time of minimum by single curve, $9^{h}\ 31^{m}.2$.

Time of minimum by mean light-curve, $9^{h}\ 34^{m}.2$.

Times of equal brightness,

	Before	After	Middle
M	h m	h m	h m
6.6	9 8.5	9 53.0	9 30.7

1889 June 5; five observations, from $9^{h}\ 40^{m}$ to $10^{h}\ 40^{m}$.

Time of minimum by single curve, $10^{h}\ 10^{m}.0$, wt. 3.

Time of minimum by mean light-curve, $10^{h}\ 10^{m}.9$.

Times of equal brightness,

	Before	After	Middle
M	h m	h m	h m
6.5	9 52.0	10 32.0	10 12.0
6.6	10 5.0	10 15.0	10 10.0
Mean of middle times			10 11.0

1889 July 1; ten observations, from $8^{h}\ 55^{m}$ to $11^{h}\ 15^{m}$.

Time of minimum by single curve, $9^{h}\ 58^{m}.7$, wt. 3.5.

Time of minimum by mean light-curve, $10^{h}\ 4^{m}.4$.

Times of equal brightness,

	Before	After	Middle
M	h m	h m	h m
6.5	9 22.0	11 0.0	10 11.0
6.6	9 42.0	10 14.0	9 58.0
Mean of middle times			10 4.5

1889 July 6; sixteen observations, from $9^{h}\ 10^{m}$ to $12^{h}\ 45^{m}$. Moon about the first quarter, and sky streaked with light cirrhus cloud.

Time of minimum by single curve, $11^{h}\ 16^{m}.0$, wt. 5.

Time of minimum by mean light-curve, $11^{h}\ 26^{m}.7$.

Times of equal brightness,

	Before	After	Middle
M	h m	h m	h m
6.4	10 27.0	12 38.0	11 32.5
6.5	10 45.5	12 20.0	11 32.7
6.6	10 56.0	11 38.0	11 17.0
Mean of middle times			11 27.4

1889 July 22; thirteen observations, from $8^{h}\ 40^{m}$ to $11^{h}\ 30^{m}$.

Time of minimum by single curve, $9^{h}\ 51^{m}.6$, wt. 5.

Time of minimum by mean light-curve, $9^{h}\ 58.5$.

Times of equal brightness,

	Before	After	Middle
M	h m	h m	h m
6.5	8 54.5	11 9.0	10 1.8
6.6	9 30.5	10 20.5	9 55.5
6.7	9 43.5	9 58.0	9 50.7
Mean of middle times			9 56.0

1889 Aug. 22; twelve observations from $8^{h}\ 25^{m}$ to $11^{h}\ 20^{m}$. After 10^{h} the sky was more or less hazy.

Time of minimum by single curve, $10^{h}\ 15^{m}.2$, wt. 4.5.

Time of minimum by mean light-curve, $10^{h}\ 16^{m}.1$.

Times of equal brightness,

	Before	After	Middle
M	h m	h m	h m
6.4	9 21.7	11 12.7	10 17.2
6.5	9 43.7	10 53.7	10 18.7
6.6	10 1.7	10 28.7	10 15.2
Mean of middle times			10 17.0

1889 Aug. 27; fifteen observations, from $7^{h}\ 55^{m}$ to $11^{h}\ 45^{m}$.

Time of minimum by single curve, $10^{h}\ 36^{m}.5$, wt. 4.5.

Time of minimum by mean light-curve. $10^{h}\ 42^{m}.4$.

Times of equal brightness,

	Before	After	Middle
M	h m	h m	h m
6.5	9 54.7	10 44.9	10 49.8
6.6	10 16.0	10 54.5	10 35.2
Mean of middle times			10 42.5

RECAPITULATION OF CAMBRIDGE MEAN TIMES OF OBSERVED MINIMA.

Star	Date	Single Curve	Mean Curve	Equal Br.
		d h m	h m	h m
U Cephei	1888 Oct.	10 11 18.4	11 13.1	11 18.2
	1889 May	5 9 16.5	9 15.0	9 13.0
U Coronae	May	18 9 18.0	9 19.5	9 19.0
	June	18 10 22.6	10 19.3	10 20.0
δ Librae	July	17 10 12.4	10 6.5	10 8.9
	July	24 10 26.7	10 13.1	10 22.1
U Ophiuchi	1889 May	26 9 26.5	9 29.2	9 25.7
	May	31 9 31.2	9 34.2	9 30.7
	June	5 10 10.0	10 10.9	10 11.0
	July	1 9 58.7	10 4.4	10 4.5
	July	6 11 16.0	11 26.7	11 27.1
	July	22 9 51.6	9 58.5	9 56.0
	Aug.	22 10 15.2	10 16.1	10 17.0
	Aug.	27 10 36.5	10 42.4	10 42.5

Dorchester, Mass., 1889 *Sept.* 12.

ON THE VARIABLE *W VIRGINIS.*

BY P. S. YENDELL.

The star, which is interesting as being the only known variable of short period, not of the *Algol*-type, of strictly telescopic magnitude, has of late years been rather neglected by observers. On this account, I began a series of observations of it this year, and have obtained twenty-two observations of it between May 21 and July 24, from which four maxima have been deduced by the use of SCHÖNFELD's light-scale and mean light-curve, as published in the *Astronomische Nachrichten*, Vol. LXXXI, p. 161. These maxima are given below :

Epoch	1889	w	O—C	O—C′
			d	d
425	May 29.1	5	—1.83	—0.46
426	June 17.16	3	—0.41	+0.93
427	July 6.06	1	+1.18	+2.56
428	20.8	1	—1.35	+0.03

The maxima of epochs 425 and 428 were deduced from single curves formed, respectively, from seven and eight observations, and are accordingly assigned the highest weight; that of epoch 426 by the use of the mean curve from four observations, one near the maximum, and three on the falling curve; and that of 427 from only two observations upon the rising curve, on which account a nominal value only has been given it.

Dorchester, 1889 *August* 24.

The star disappears at minimum in my telescope.

As the residuals from these observations appear to indicate a sensible correction to SCHÖNFELD's elements, an attempt has been made to determine the value of such corrections; by treating these residuals in connection with those of SCHÖNFELD's to which access was available, namely, from the star's discovery in 1866 until 1872, covering in all 122 periods of the star, and applying the method of least-squares, a correction appears to be indicated to the principal epoch of $+0^d.0123$, and to the period of $-0^d.00276$. The resulting elements are, 1869 April 25.678 + $17^d.26987$ *E*.

The residuals obtained by the use of these elements show a mean, by weights, of $+0^d.052$, as compared with $-0^d.16$ from those of SCHÖNFELD; the earliest and latest groups of observations are better represented by them, and the intervening ones at least as well.

The above attempt at a determination is, from the nature of the case, provisional, my own observations not furnishing sufficient material for either a mean curve, or a fairly definitive light-scale; but it may be of some use pending a more definitive discussion.

The residuals given by my own observations, by the use of the above elements, are given in the table of maxima above, under the heading O—C′.

OCCULTATION OF *JUPITER*, 1889 SEPTEMBER 3.

OBSERVED AT THE HALSTED OBSERVATORY, PRINCETON, N.J.

BY C. A. YOUNG.

It was intended to observe the phenomenon spectroscopically, but on making the necessary preparations it was found impossible, on account of the extreme haziness of the air, to get a spectrum of *Jupiter* bright enough to show the lines distinctly; in the spectrum of the moon even they were hardly visible. The plan was therefore reluctantly abandoned, and I contented myself with simple time observations.

The instants of immersion were observed as follows :

	Sid. T.		G.M.T.
	h m s		h m s
Third satellite (centre)	20 36 57.8	=	14 41 55.9
Second “ “	40 29.6		45 27.1
Fourth “ “	45 44.3		50 41.0
Jupiter { 1st contact	[*]47 7.8		[*]52 4.3
2d “	48 13.1		53 9.4
First satellite	20 48 42.5	=	14 53 38.7

The whole aperture of the telescope, 23 inches, was used, with a power of 480. The moon's dark limb as it crossed the planet's disc was sharply defined, and no sensible distortion of the outline of the disc could be detected, nor any change in the appearance of the markings on the planet's surface; but the light was so feeble that they were not very well seen.

At emersion the planet was so much lower, and the haze so much thicker, that it was necessary to reduce the power to 160; with this, the moon's surface, in color and brightness, looked much like a piece of orange peel.

Emersions were noted as follows:

	Sid. T.		G.M.T.
	h m s		h m s
Third satellite	21 26 47.3	=	15 31 37.3
Second satellite	21 31 3.4	=	15 35 52.6

Before the fourth satellite reappeared a bank of fog obscured the moon so that the satellite was not seen until it was some seconds distant from the moon's limb. The edge of the planet was first dimly seen through the fog, emerging from behind the moon at $21^{h}\ 36^{m}\ 16^{s}$ Sid. T = $15^{h}\ 41^{m}\ 4^{s}.5$ G.M.T., probably a number of seconds late. At $21^{h}\ 37^{m}\ 41^{s}$ Sid. T. = $15^{h}\ 42^{m}\ 29^{s}.5$ G.M.T., I thought the planet's disc was clear of the moon, but the image was so faint that I have no confidence in the observation. The first satellite was not seen at all after its emersion.

Princeton, N. J., 1889 *Sept.* 9.

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[*] I suspect an error of one minute here (46 instead of 47). I noted the seconds myself, from the magnet beat of the clock, but the minutes were noted by my assistant, who called off every tenth second from the clock-face. The interval between the two contacts ought to be about two minutes, according to Mr. BELLAMY (*A.J.* 201).

OCCULTATION OF *JUPITER*, 1889 SEPTEMBER 3,

AS OBSERVED AT THE LICK OBSERVATORY.

OBSERVATIONS OF **J. E. KEELER.**

For observing the occultation of *Jupiter* on the afternoon of Sept. 3, I used a power of 261 on the 36-inch equatorial, and recorded time on a chronograph by the No. 7 clock, which is regulated to Pacific Standard Time.

Observation was begun about twenty minutes before the time of first contact, as computed by Mr. HILL, in order to note the disappearance of the satellites, but although the satellites were visible, they were too faint to be held steadily, and the attempt was abandoned. The seeing was not very good, and the disc of *Jupiter* was pale and rather ill-defined. The stronger markings on his surface could be made out fairly well. The advancing limb of the moon was entirely invisible.

At every suspected flattening of the limb of *Jupiter* I touched the key. The time recorded, when I was *sure* that first contact had occurred, was $5^{h}\ 32^{m}\ 14^{s}.9$, and was estimated to be 2^{s} late.

At the disappearance of *Jupiter* the light seemed to persist remarkably after the time of geometrical contact, but by comparing the time required for the moon to cover his disc with the observations of others, and with those made at emersion, it appears probable that this was an illusion. The last glimmer of light was noted at $5^{h}\ 34^{m}\ 24^{s}.5$.

When the telescope (which had remained clamped in declination) was directed to the bright limb of the moon about ten minutes before the computed time of emersion, the third satellite was seen at a little distance, and shortly afterward, at $6^{h}\ 18^{m}\ 12^{s}.1$ satellite II was seen about 5^{s} clear of the limb. The point of reappearance was thus exactly indicated.

At $6^{h}\ 23^{m}\ 22^{s}.0$ satellite IV was first seen, 2^{s} clear of the limb of the moon.

The limb of *Jupiter* was first visible, 1^{s} clear of the moon, at $6^{h}\ 25^{m}\ 52^{s}.0$. As the disc emerged, the belts and other markings were well seen. The great red spot had just crossed the meridian, the notch following it on the southern equatorial belt being almost exactly central.

The fourth contact was difficult, on account of the brightness of the moon and the defective illumination of *Jupiter's* preceding limb. It was recorded at $6^{h}\ 28^{m}\ 12^{s}.5$.

Satellite I was first seen at $6^{h}\ 29^{m}\ 47^{s}.6$, by estimate 1^{s} clear of the moon.

Clock No. 7 was found by Mr. HILL to be $0^{s}.49$ slow of Pacific Standard Time. Applying this correction, reducing to Lick Observatory mean-time, and allowing for the estimated error of each observation as recorded above, we have the following as the results of the contact observations.

	L.O. Mean Time		
	h	m	s
First contact	5	25	39.1
Second contact	5	27	50.7
Reappearance of satellite II	6	11	33 ±
Reappearance of satellite IV	6	16	46.2
Third contact	6	19	17.2
Fourth contact	6	21	39 ±
Reappearance of satellite I	6	23	12.8

OBSERVATIONS OF E. E. BARNARD.

The occultation of *Jupiter* by the moon Sept. 3 was observed with the 12-inch equatorial, a magnifying power of 150 being used. Mr. HILL had graphically computed the times of the different phenomena.

IMMERSION.

The satellites could not be seen at immersion. There seemed to be a faint outline of light bounding the moon's edge where it crossed *Jupiter*. This was probably an effect of contrast. A large mountain broke the curve of the moon's limb, and was seen to shift its place on the disc of *Jupiter* as the planet moved diagonally behind. The seeing was poor (= 2), and the second contact was observed only as a slowly fading diffused spot or glow of light, as if the planet were disappearing through a dense atmosphere.

	L.O. Mean Time			
	h	m	s	
First contact	5	25	41.3	quite good
Second contact	5	27	47.3	good

EMERSION.

Through having inadvertently fixed the eye on the wrong point of the moon's limb, the planet was not seen at the third contact until a considerable fraction of the disc had emerged, and the time was not noted. Fourth contact, $6^h 21^m 38^s.3$, very uncertain. A rather singular phenomenon occurred just before last contact, that completely vitiated any accurate observation. The edge of the moon crossing *Jupiter* was bordered by a diffused dark shading, probably 4″ or 5″ wide; through this the planet was seen to be badly distorted, and completely obliterated near the moon's limb. When the limb of *Jupiter* was finally seen it was very faint, and appeared to be pushed up towards the center of the planet.

It seemed to me that this dark bordering of the moon's edge extended all around the bright limb, and not only where it crossed *Jupiter*, and was probably due to the bad seeing.

The following estimates were made of the apparent bisection of *Jupiter's* disc by the moon.

	h	m	s	
Immersion, ½ obscured	5	26	46.2	
Emersion, ½ uncovered	6	19	53.1	
First satellite at emersion	6	23	15.7	(uncertain)

The entire occultation was over before sunset. These records are in Mt. Hamilton mean time.

Mt. Hamilton, 1889 *Sept*. 3.

OBSERVATIONS OF CHARLES B. HILL.

I observed the occultation of *Jupiter* by the moon on the afternoon of September 3, 1889, using the 6½-inch equatorial. Previous to the phenomenon, I compared all the chronometers with the standard clock (they are also compared at 10 A.M. each day). Times were noted on M.T. Chronometer No. 1667, in my own observations, which follow:

IMMERSION.

With power of about 75 diameters. Planet fairly bright, moon's limb invisible; could not see any of the satellites. Notch in *Jupiter* first noticed at $5^h 25^m 31^s.7$ by chronometer, and recorded "probably 3^s–5^s late." The disappearance seemed perfectly normal until near the last, when the minute segment of the planet remaining grew very indistinct, and was by no means the sharp fine line which the moderately good definition would have inclined the observer to expect. Final disappearance was recorded at $5^h 27^m 36^s$.

EMERSION.

Eyepiece changed for one of 150 diameters. There being no position-circle available, I depended upon an estimated point of emergence which proved to be considerably too far north. The recorded time, $6^h 19^m 13^s$ by chronometer, is late: when first seen the planet was uncovered to a depth of about 3″±. [From the projection of the occultation which I made for the predicted times, this estimation would give true contact about 7^s earlier.] This segment when first seen was exceedingly faint in comparison with the bright, sharp border of the moon; as emergence progressed the planet seemed to become much brighter, and the two satellites which had preceded were clearly visible. The markings on *Jupiter* were plain enough, except at the moon's limb, and here there seemed to be a marked shading — a fringe of 6″ or 8″ in width. The effect was probably analogous to the irradiation visible on the limb above and below the planet, but it certainly seemed very exaggerated. It made the emerging border so indistinct that last contact was one of the most difficult to note. I placed it at $6^h 21^m 27^s.5$ by chronometer. The last satellite (I) was caught at $6^h 23^m 4^s$, when well clear of the moon's limb, "2 or 3 seconds late."

The correction to chronometer on L.O. mean time was $+11^s.8$ at immersion, and $+12^s.0$ at emersion; the corrected times are:

IMMERSION.

	h	m	s	
Contact I,	5	25	43.5	; "3 to 5s late."
Contact II,	5	27	47.8	; fairly good.

EMERSION.

Contact III,	6	19	25.0	; [7s late.]
Contact IV,	6	21	39.5	; doubtful.
Satellite I,	6	23	16.0	; "2–3 secs. late."

Observations of ARMIN O. LEUSCHNER.

The contacts were observed with the 4-inch broken-tube comet-seeker of the Lick Observatory, and a power of about 50 diameters. In his report on the occultation of *Jupiter*, 1889 March 23, Mr. Hill has pointed out that the prism of this instrument gives rather poor images of bright stars and planets. The times were taken from siderial chronometer No. 1720.

Immersion.

The moon's limb was rather unsteady before immersion, and this, as well as the bright daylight, rendered the observation of the first two contacts quite difficult. The times were noted as follows:

	L.O.M.T.	
First contact,	$5^h\ 25^m\ 41^s.6$	good.
Second contact,	5 27 43 .9	"

At second contact *Jupiter* disappeared from two to three times. The last glimpse of it was caught at the time given above.

Emersion.

At emersion the atmospheric disturbance had almost ceased, and the moon's limb was well defined. *Jupiter's* limb was first seen at

$6^h\ 19^m\ 26^s.2$

The fourth contact occurred at

$6^h\ 21^m\ 32^s.2$ good.

The satellites were not seen at all.

Lick Observatory, 1889 *September*.

OCCULTATION OF *JUPITER*, 1889 SEPTEMBER 3,

BY W. H. NUMSEN.

The phenomena of the immersion were well observed, the sky around the moon being generally clear. At emersion *cirro-stratus* clouds interfered, and the planet was not seen until some minutes afterwards.

Definition at immersion was only fair, the limb boiling, and the satellites dancing at times. The dark limb of the moon could not be seen through the telescope, and the times given below are for the total disappearance of the satellites, and for first and second contact of *Jupiter's* limb. The telescope was a 4-inch equatorial, by Cooke of York, Eng.; power used 120. Latitude of observatory 39° 21′. Longitude, $1^m\ 20^s$ east of Washington.

Denmore Observatory, Baltimore, Md., 1889 *Sept.* 7.

		h	m	s
Third satellite		9	39	23
Second satellite		9	43	57
Fourth satellite		9	49	15
Jupiter	1st contact	9	49	46
	2d contact	9	51	45
First satellite		9	52	13

Seventy-fifth meridian time was used, and the correct time was known by comparing my watch with the Washington noon-signal on Sept. 2, 3, 4, when its rate was found to be small.

FILAR-MICROMETER OBSERVATIONS OF COMET *c* 1889 (*BARNARD June* 23),

MADE WITH THE 12-INCH EQUATORIAL,

BY E. E. BARNARD, ASTRONOMER OF THE LICK OBSERVATORY.

1889 Mt. Hamilton M.T.	∗	No. Comp.	☄ — ∗		☄'s apparent		log pΔ	
			Δα	Δδ	α	δ	for α	for δ
d h m s			m s	′ ″	h m s	° ′ ″		
July 31 14 15 37	15	6 , 6	−3 7.73	+0 12.9	4 7 45.96	+49 46 45.5	n9.826	0.413
Aug. 6 15 0 59	16	2	–	+8 37.6	–	+50 1 51.4	–	
6 15 12 21	16	3	+2 27.44	–	4 28 49.22	–	n9.814	9.987

Mean Places for 1889.0 of Comparison-Stars.

∗	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
15	4 10 53.33	+0.36	+49 46 41.9	−9.3	Oe. Arg. 4671
16	4 26 21.22	+0.51	+49 53 23.0	−9.2	½(Oe.Arg.4915-16+Radcliffe 1255)

August 6. The comet was of the last degree of faintness, and was observed with the utmost difficulty. These close the observations of this comet.

COMET 1888 V.

BY E. E. BARNARD, ASTRONOMER OF THE LICK OBSERVATORY.

This comet, which was discovered here on the morning of Oct. 31, 1888, has differed considerably in its brightness from what would be expected from the laws of reflection alone.

On Jan. 29, it was pretty bright with a star-like nucleus, and a tail 20′ long. In February and March, it was about as bright as when discovered, five months before, being an easy object in the $3\frac{1}{4}$-inch finder. About April 3, it was very faint and difficult; while on April 26, it was brighter, and had a star-like nucleus of the thirteenth magnitude.

In the last observations it was extremely small: about 10″ in diameter, very faint, but a little brighter in the middle.

The following is a continuation of the observations previously published in *Astronomical Journal*, No. 185.

FILAR-MICROMETER OBSERVATIONS OF COMET 1888 V,

MADE WITH THE 12-INCH EQUATORIAL OF THE LICK OBSERVATORY.

BY E. E. BARNARD.

Mt. Hamilton M.T. 1888–89	*	No. Comp.	☄ — * Δα	☄ — * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
d h m s			m s	′ ″	h m s	° ′ ″		
Nov. 28 14 26 24	10	6 , 3	—2 17.72	—2 33.6	10 18 2.80	— 9 30 6.1	n9.556	0.778
28 14 26 24	11	6	—1 40.39	–	10 18 2.8	–	n9.556	–
Dec. 5 14 54 0	12	10 , 6	—0 45.84	+2 15.1	10 23 0.3	— 7 30.0	9.514	0.774
Jan. 23 10 52 29	13	10 , 7	—0 28.82	+5 30.8	10 11 43.67	+15 26 53.6	n9.560	0.583
29 13 0 23	14	12 , 6	—0 10.56	—1 19.2	10 5 22.89	+18 50 25.2	n8.732	0.442
Feb. 8 15 53 21	15	12 , 7	—0 27.28	—2 36.8	9 53 57.83	+24 2 40.7	9.591	0.480
Mar. 1 9 15 36	16	6 , 6	—2 16.55	+6 59.6	9 32 45.30	+31 53 50.1	n9.356	0.049
Apr. 3 10 10 58	17	16 , 6	—1 25.87	—1 13.5	9 20 10.89	+37 8 13.4	9.396	9.623
26 9 50 53	18	8 , 6	—0 29.98	+1 51.0	9 28 39.33	+37 44 14.4	9.595	9.991
27 11 13 54	18	14 , 5	+0 6.50	+1 34.3	9 29 15.78	+37 43 54.8	9.720	0.356
28 10 29 39	18	16 , 6	+0 41.35	+1 1.2	9 29 50.64	+37 43 21.8	9.673	0.210
29 9 33 0	18	10 , 6	+1 16.60	+0 25.8	9 30 25.84	+37 42 49.5	9.562	9.959
29 10 13 28	19	10 , 7	—1 34.04	+0 18.7	9 30 27.08	+37 42 53.9	9.671	0.113
May 3 11 4 21	20	8 , 3	—1 21.75	—0 16.7	9 33 2.28	+37 38 31.3	9.740	0.393
17 9 22 36	21	8 , 7	+0 53.02	—0 22.5	9 43 38.45	+37 15 35.7	9.659	0.190
19 9 3 51	21	8 , 5	+2 34.71	—4 54.5	9 45 20.24	+37 11 3.8	9.639	0.149
21 10 18 56	22	4 , 3	—0 2.56	+5 9.6	9 47 8.26	+37 5 58.3	9.716	0.456
22 10 3 0	22	8 , 5	+0 48.94	+2 37.6	9 47 59.80	+37 3 26.4	9.620	0.100

Mean Places for 1888.0 and 1889.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place.	Authority
	h m s	s	° ′ ″	″	
10	10 20 18.64	+1.88	— 9 27 37.7	+5.2	Weisse's Bessel 10^h, 318 (10^h, 318
11*	10 19 41.30	+1.89	— 9 29.7		SDM. —9° 3069 comp. in α with W.B.
12	10 23 44.0	+2.09	— 7 32.3	+3.5	SDM. —7° 3044
13	10 12 11.53	+0.36	+15 21 26.8	—1.0	Rümker, *Nach.* No. 7
14	10 5 33.03	+0.42	+18 51 49.8	—5.4	Weisse's Bessel 10^h, 58–59
15	9 54 24.40	+0.71	+24 5 23.0	—5.5	Lalande 19544
16	9 35 1.00	+0.85	+31 46 53.4	—2.9	Weisse's Bessel 9^h, 696
17	9 22 6.27	+0.19	+37 9 23.9	+3.0	Weisse's Bessel 9^h, 418
18	9 29 9.16	+0.15	+37 42 17.8	+5.6	Comp. with Weisse's Bessel 9^h, 488
		+0.12		+5.6	
		+0.10		+5.8	
		+0.08		+5.9	
19	9 32 1.02	+0.10	+37 42 27.5	+7.7	Comp. with *18
20	9 34 23.99	+0.04	+37 38 42.0	+6.0	Comp. with Weisse's Bessel 9^h, 736
21	9 42 45.35	+0.08	+37 15 51.6	+6.6	Weisse's Bessel 9^h, 856
		+0.15		+6.7	
22	9 47 10.59	+0.23	+37 0 41.9	+6.8	Comp. with Weisse's Bessel 9^h, 896
		+0.27		+6.9	

---

* R.A. of SDM. is 1ˢ too great.

Star–Comparisons.

Stars	Comp.	$\Delta\alpha$	$\Delta\delta$
		m s	′ ″
No. 11 —W. Bessel 10h, 318	6	−0 37.34	
18 —W. Bessel 9h, 488	6.3	+3 33.63	−2 56.7
19 —No. 18	4.3	+2 51.86	+0 9.7
20 —W. Bessel 9h, 736	4.3	−1 54.75	+0 32.7
22 —W. Bessel 9h, 896	6.3	+2 41.06	+0 12.2

Mt. Hamilton, 1889 *September*.

EPHEMERIS OF COMET *d* 1889,

(Continued from page 80.)

Gr.M.T. 1889	App. α	App. δ	log *r*	log Δ	Br.	Gr.M.T. 1889	App. α	App. δ	log *r*	log Δ	Br.
	h m s	° ′					h m s	° ′			
Oct. 16.5	23 42 36	−4 10.2	0.3046	0.0371	1.90	Oct. 30.5	23 42 27	−2 53.0			
18.5	42 16	4 0.7				Nov. 1.5	42 53	2 39.9	0.3095	0.0835	1.50
20.5	41 59	3 50.7	0.3056	0.0474	1.80	3.5	43 27	2 26.4			
22.5	41 51	3 40.2				5.5	44 7	2 12.4	0.3110	0.0966	1.40
24.5	41 49	3 29.2	0.3068	0.0588	1.70	7.5	44 54	1 57.9			
26.5	41 55	3 17.6				Nov. 9.5	23 45 47	−1 13.0	0.3126	0.1102	1.31
Oct. 28.5	23 42 7	−3 5.6	0.3081	0.0708	1.60						

EPHEMERIS OF VARIABLES OF THE *ALGOL*-TYPE.

Approximate Greenwich M.T., 1889.

For remarks and comparison-stars, see Vol. VII, p. 187 ff. The uncertainty which has for some time existed as to the time of minimum of *Y Cygni* has been in a measure removed by observation of a minimum, imperfectly obtained, on 1889 Aug. 25, at about 16h Gr. M.T.: on which depend the times given below, as well as those in the ephemeris in No. 201. From lack of recent observations the epoch for *R Canis Majoris* is now somewhat uncertain, perhaps by a couple of hours.

	October			October			October			October			October	
	d	h		d	h		d	h		d	h		d	h
U Cephei	9	15	*U* Cephei	14	15	*U* Ophiuchi	19	12	*U* Cephei	24	14	Algol	29	11
Y Cygni	9	16	*R* Canis Maj.	15	15	*U* Cephei	19	14	*R* Canis Maj.	24	16	*U* Ophiuchi	29	13
U Coronae	10	13	*Y* Cygni	15	16	*U* Ophiuchi	20	8	*Y* Cygni	24	16	*U* Cephei	29	14
Algol	12	6	λ Tauri	16	10	λ Tauri	20	8	*S* Cancri	24	22	*U* Ophiuchi	30	9
λ Tauri	12	11	*R* Canis Maj.	16	17	*Y* Cygni	21	16	*U* Ophinchi	25	9	*Y* Cygni	30	16
Y Cygni	12	16	U Coronae	17	11	*R* Canis Maj.	23	13	*R* Canis Maj.	25	20	*R* Canis Maj.	31	12
U Ophiuchi	13	15	*R* Canis Maj.	17	21	Algol	23	17	Algol	26	14			
U Ophiuchi	14	11	*Y* Cygni	18	16	*U* Ophiuchi	24	12	*Y* Cygni	27	16			

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ON LEVERRIER'S DETERMINATION OF THE SECOND-ORDER TERMS IN THE SECULAR MOTIONS OF THE ECCENTRICITIES AND PERIHELIA OF *JUPITER* AND *SATURN*.

By G. W. Hill.

I wish to call attention to some remarkable peculiarities in the results obtained by LeVerrier (*Annales de l'Observatoire de Paris, Mémoires*, Tom. X, pp. 239-260). It is well known that these terms augment the motion of the mentioned elements, which is obtained from the sole consideration of the first power of the disturbing force, by nearly a fourth part. Hence their importance from a practical point of view. The subject is treated again by LeVerrier (Tom. XI, pp. 20, 23, 53, 56). Taking from the latter place the numerical data we need for our discussion, the terms involving the relative position of the planes of the orbits may be set aside as having scarcely any importance in the matter; also the few terms of the third and fourth orders with respect to the disturbing forces, which LeVerrier has derived, and which scarcely augment the precision of his final results, may be neglected. For LeVerrier's values of the masses let Bessel's values $m = \frac{1}{1047.879}$, $m' = \frac{1}{3501.6}$ be substituted.

With these modifications, no longer keeping separate the portions having different mass-multipliers, LeVerrier's results take the reduced form of the four following differential equations which the variables e, $\tilde{\omega}$, e' and $\tilde{\omega}'$ must satisfy: —

$$\begin{aligned}
\frac{e}{\cos\varphi}\frac{d\tilde{\omega}}{dt} = {} & + 8''.243933\,e + 18''.7566\,e^3 + 263''.169\,ee'^2 + 2437''.73\,e^5 + 40886''.0\,e^3e'^2 + 56352''.0\,ee'^4 \\
& + \left\{\begin{matrix} -\ 4''.665835\,e' - 239''.065\,e^2e' - 205''.900\,e'^3 \\ -\ 20396''.8\,e^4e' - 101809''.8\,e^2e'^3 - 30842''.5\,e'^5 \end{matrix}\right\}\cos(\tilde{\omega}'-\tilde{\omega}) \\
& + \{123''.837\,ee'^2 + 27073''.9\,e^3e'^2 + 37132''.8\,ee'^4\}\cos 2(\tilde{\omega}'-\tilde{\omega}) \\
& - 11105''.2\,e^2e'^3\cos 3(\tilde{\omega}'-\tilde{\omega}),
\end{aligned}$$

$$\begin{aligned}
\frac{1}{\cos\varphi}\frac{de}{dt} = {} & \left\{\begin{matrix} 5''.224151\,e' + 79''.688\,e^2e' + 205''.900\,e'^3 \\ +\ 1063''.56\,e^4e' + 33901.1\,e^2e'^3 + 30842''.5\,e'^5 \end{matrix}\right\}\sin(\tilde{\omega}'-\tilde{\omega}) \\
& - \{123''.837\,ee'^2 + 13516''.86\,e^3e'^2 + 37132''.8\,ee'^4\}\sin 2(\tilde{\omega}'-\tilde{\omega}) \\
& + 11105''.2\,e^2e'^3\sin 3(\tilde{\omega}'-\tilde{\omega}),
\end{aligned}$$

$$\begin{aligned}
\frac{e'}{\cos\varphi'}\frac{d\tilde{\omega}'}{dt} = {} & + 18''.12312\,e' + 648''.265\,e^2e' + 828''.207\,e'^3 + 125176''.4\,e'^5 \\
& + 277780''.7\,e^2e'^3 + 50369''.6\,e^4e' \\
& + \left\{\begin{matrix} -\ 12''.482489\,e - 196''.160\,e^3 - 1523''.643\,ee'^2 \\ -\ 10061''.7\,e^5 - 250947''.1\,e^3e'^2 - 380667''\,ee'^4 \end{matrix}\right\}\cos(\tilde{\omega}'-\tilde{\omega}) \\
& + \{305''.012\,e^2e' + 183474''.2\,e^2e'^3 + 33426''.6\,e^4e'\}\cos 2(\tilde{\omega}'-\omega) \\
& - 27503''.5\,e^3e'^2\cos 3(\tilde{\omega}'-\tilde{\omega}),
\end{aligned}$$

$$\begin{aligned}
\frac{1}{\cos\varphi'}\frac{de'}{dt} = {} & \left\{\begin{matrix} -\ 12''.482489\,e - 196''.160\,e^3 - 507''.856\,ee'^2 \\ -\ 10061''.7\,e^5 - 83757''.2\,e^3e'^2 - 76591''\,ee'^4 \end{matrix}\right\}\sin(\tilde{\omega}'-\tilde{\omega}) \\
& + \{305''.012\,e^2e' + 91976''.7\,e^2e'^3 + 33426''.6\,e^4e'\}\sin 2(\tilde{\omega}'-\tilde{\omega}) \\
& - 27503''.5\,e^3e'^2\sin 3(\tilde{\omega}'-\tilde{\omega}).
\end{aligned}$$

Some of the coefficients in these equations are identical, and others are seen to satisfy certain relations. To explain these, it may be remarked that when we confine our attention to the first power of the disturbing force, the second members of the equations are constant multiples of the partial derivatives of the same function R, so that representing one of the terms of R by

$$Ae^{i}e'^{i'}\cos j(\hat{\omega}'-\hat{\omega}),$$

we have

$$\frac{e}{\cos\varphi}\frac{de}{dt}=-\frac{1}{m\sqrt{\mu a}}\frac{\partial R}{\partial\hat{\omega}}=-\frac{1}{m\sqrt{\mu a}}jAe^{i}e'^{i'}\sin j(\hat{\omega}'-\hat{\omega}),$$

$$\frac{e}{\cos\varphi}\frac{d\hat{\omega}}{dt}=\frac{1}{m\sqrt{\mu a}}\frac{\partial R}{\partial e}=\frac{1}{m\sqrt{\mu a}}iAe^{i-1}e'^{i'}\cos j(\hat{\omega}'-\hat{\omega}),$$

$$\frac{e'}{\cos\varphi'}\frac{de'}{dt}=-\frac{1}{m'\sqrt{\mu'a'}}\frac{\partial R}{\partial\hat{\omega}'}=\frac{1}{m'\sqrt{\mu'a'}}jAe^{i}e'^{i'}\sin j(\hat{\omega}'-\hat{\omega}),$$

$$\frac{e'}{\cos\varphi'}\frac{d\hat{\omega}'}{dt}=\frac{1}{m'\sqrt{\mu'a'}}\frac{\partial R}{\partial e'}=\frac{1}{m'\sqrt{\mu'a'}}i'Ae^{i}e'^{i'-1}\cos j(\hat{\omega}'-\hat{\omega}).$$

But when we wish to add to the terms of the first order with respect to disturbing forces those of two dimensions with respect to the same quantities, the foregoing relations are no longer rigorously fulfilled, because some of the new terms result from the substitution in the portion of the perturbative function which denotes the reaction of the planet on the sun, and for which we do not pass from the value for one planet to that for the other by multiplying by a constant.

However, certain considerations connected with the possibility of having the same perturbative function for both planets, through an orthogonal transformation of variables, would seem to show that the relations given above could not be greatly disturbed.

For the purpose of exhibiting this quality from the four equations which have been given, we remark that they will furnish from one to four values for A, the coefficient of any term of R.

I have prepared the following table showing the agreement or disagreement of the several values. To obtain it we make the following assumptions: let the linear unit adopted be the semi-axis major of *Saturn*, then the logarithm of that of *Jupiter* will be 9.7367410, and the mass of the Sun being denoted by unity, we shall have

$$\log\left(\frac{1}{m\sqrt{\mu a}}\right)=3.1517336,\quad \log\left(\frac{1}{m'\sqrt{\mu'a'}}\right)=3.5442045.$$

Term of R	Values of A from Equations			
	I.	II.	III.	IV.
	″	″	″	″
Ae^2	+ 0.002906504			
Ae'^2			+ 0.002588204	
Ae^4	+ 0.00859488			
$Ae^2e'^2$	+ 0.0927836		+ 0.0925802	
Ae'^4			+ 0.0591391	
Ae^6	+ 0.28648			
$Ae^4e'^2$	+ 7.2074		+ 7.1934	
$Ae^2e'^4$	+19.8219		+19.8352	
Ae'^6			+ 5.9589	
$Aee'\cos(\omega'-\omega)$	− 0.003289999	− 0.003683681	− 0.003565305	− 0.003565305
$Ae^3e'\cos(\omega'-\omega)$	− 0.056190	− 0.056190	− 0.056028	− 0.0056028
$Aee'^3\cos(\omega'-\omega)$	− 0.145185	− 0.145185	− 0.145063	− 0.145063
$Ae^5e'\cos(\omega'-\omega)$	− 2.87646	− 2.86532	− 2.87387	− 2.87387
$Ae^3e'^3\cos(\omega'-\omega)$	−23.9296	−23.9066	−23.8922	−23.9231
$Aee'^5\cos(\omega'-\omega)$	−21.7478	−21.7478	−21.7456	−21.8763
$Ae^2e'^2\cos 2(\omega'-\omega)$	+ 0.0436603	+ 0.0436603	+ 0.0435595	+ 0.0435595
$Ae^4e'^2\cos 2(\omega'-\omega)$	+ 4.77262	+ 4.76554	+ 4.77373	+ 4.77373
$Ae^2e'^4\cos 2(\omega'-\omega)$	+13.0916	+13.0916	+13.1012	+13.1354
$Ae^3e'^3\cos 3(\omega'-\omega)$	− 2.61019	− 2.61019	− 2.61856	− 2.61856

It will be noticed that there is approximate agreement generally between the different values. The largest discrepancy occurs in the case of the coefficient of $ee'\cos(\hat{\omega}'-\hat{\omega})$, where we have the anomaly of the values from the third and fourth equations agreeing, while those from the first and second are at variance. In the equations determining the elements of *Saturn* we have the two coefficients −12″.482489, −12″.482489, exactly identical, while, in the equations for the elements of *Jupiter*, the analogous coefficients —4″.665835, —5″.224151, differ. How to explain this anomaly without supposing some error in LeVerrier's numbers, I cannot imagine. The details, given in LeVerrier's volumes, are too slight to enable us to trace this anomaly to its origin. After transformation to our values of the masses, the several portions given for the composition of these discrepant numbers stand as follows:—

$$-\ 4''.830777 - 0''.111542 + 0''.279158 - 0''.002671 = -\ 4''.665835,$$

$$-\ 4''.830777 - 0''.111542 - 0''.279158 - 0''.002671 = -\ 5''.224151,$$

$$-\ 11''.925816 - 0''.287959 - 0''.268714 = -\ 12''.482189,$$

$$-\ 11''.925816 - 0''.287959 - 0''.268714 = -\ 12''.482189.$$

Four parts are given in the case of *Jupiter*, while, for *Saturn*, there are only three. Perhaps we must suppose that the term lacking for *Saturn* is too insignificant to be considered. It should be noticed that, in the case of *Saturn*, the three portions are proportional severally to m, mm' and m^2; while, for *Jupiter*, the four parts are proportional severally to m', m'^2, mm' and mm'. It will be perceived that the discrepancy between the two numbers for *Jupiter* is owing to the quantity 0″.279158 having opposite signs in the two equations. It does not appear easy to imagine reasons why two quantities, which are identical in the case of *Saturn*, should have opposite signs in the case of *Jupiter*. The supposition that LeVerrier attributed the wrong sign to one or the other of these numbers does not seem to set matters right. The consideration of this enigma is commended to those interested in celestial mechanics.

Washington, D.C., 1889 *October* 3.

OBSERVATIONS OF COMETS

MADE WITH THE 15-INCH EQUATORIAL OF THE HARVARD COLLEGE OBSERVATORY,

By O. C. WENDELL, Assistant.

[Communicated by Prof. Edward C. Pickering, Director.]

Greenwich M.T.			*	No. Comp.	☄ — * Δα	☄ — * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
					Comet 1887 V (Olbers).					
		d h m s			m s	′ ″	h m s	° ′ ″		
1887	Sept.	16 21 27 2	1	5	—0 35.69	—14 37.3	10 16 43.35	+29 56 31.6	9.702	0.699
	Oct.	19 21 55 37	2	5	—0 29.47	+ 0 3.2	12 55 32.80	+22 22 12.0	9.675	0.732
		21 21 45 33	3	5	—3 26.58	+ 3 47.3	13 4 14.74	+21 39 52.5	9.672	0.742
		30 22 10 17	4	1	—2 25.97	+ 4 22.8	13 41 29.28	+18 19 39.3	9.662	0.736
1888	Jan.	11 22 48 9	5	10	—0 20.12	— 9 19.5	17 1 14.77	— 2 16 15.6	9.548	0.785
		18 22 12 46	6	6	—4 2.44	+17 3.1	17 12 47.31	— 3 20 12.1	9.569	0.788
					Comet 1889 *I* (Barnard, 1888 *Sept.* 2).					
1888	Oct.	29 16 3 38	7	5	+1 3.17	— 7 26.9	5 35 22.39	+ 3 29 50.0	*n*9.556	0.756
		30 15 56 43	8	5	—0 40.43	— 1 37.5	5 31 19.66	+ 3 13 48.5	*n*9.551	0.758
		31 16 8 32	9	5	—0 16.21	— 5 11.7	5 27 1.62	+ 1 58 43.5	*n*9.523	0.763
	Nov.	1 16 9 47	10	7	+0 35.31	— 1 32.4	5 22 37.61	+ 2 40 23.5	*n*9.508	0.758
		3 15 53 16	11	5	+0 11.83	+ 3 30.6	5 13 40.16	+ 2 0 48.1	*n*9.501	0.762
		7 15 53 26	12	5	+0 55.40	+ 1 13.8	4 52 35.27	+ 0 50 41.2	*n*9.431	0.768
		12 15 52 36	13	5	+2 3.25	— 1 9.1	1 22 50.36	— 0 49 58.9	*n*9.291	0.780
		14 13 35 13	14	7	+1 0.71	+ 0 39.7	1 12 5.71	— 1 24 22.1	*n*9.558	0.780
		13 52 22	“	5	+0 55.98	+ 0 21.0	1 12 1.01	— 1 24 37.8	*n*9.531	0.780
		21 14 0 41	15	5	+1 16.43	+ 1 53.3	3 22 26.62	— 3 49 31.1	*n*9.340	0.800
	Dec.	6 15 45 28	16	5	—3 21.93	+ 3 10.7	1 45 49.95	— 7 4 39.2	9.402	0.817
		12 14 17 6	17	5	—1 17.17	— 3 0.7	1 16 57.85	— 7 32 50.7	9.286	0.823
		14 12 58 59	18	5	—1 53.48	+ 6 45.2	1 8 47.63	— 7 37 30.6	8.906	0.829
		14 5 19	“	5	—2 4.70	+ 6 37.8	1 8 36.11	— 7 37 38.0	*n*9.302	0.823
		18 13 52 20	19	5	+0 49.12	— 6 11.0	0 53 43.53	— 7 41 21.6	*n*9.360	0.822
		19 13 2 41	20	5	+1 22.48	+ 9 14.3	0 50 27.69	— 7 43 26.1	9.199	0.826
		22 15 15 3	21	5	—1 8.26	+ 1 58.9	0 40 19.81	— 7 39 6.7	*n*9.608	0.791
1889	Jan.	3 13 58 59	22	4	—3 32.34	— 5 2.0	0 13 47.14	— 7 9 51.7	9.576	0.801
		19 13 14 31	23	3	+1 50.43	— 0 52.2	23 50 28.01	— 6 20 19.3	9.615	0.790
		21 13 59 40	24	5	+0 51.17	+ 7 50.5	23 52 16.78	— 5 56 44.0	9.639	0.780

Greenwich M.T.	*	No. Comp.	☄ — * $\Delta\alpha$	☄ — * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
Comet 1888 V (Barnard, *Oct.* 30).								
d h m s			m s	′ ″	h m s	° ′ ″		
1888 Nov. 1 20 53 56	25	5	+1 15.65	—11 10.8	9 46 11.12	—15 1 54.1	n9.487	0.845
1889 Jan. 25 16 8 50	26	5	—0 47.33	— 4 20.7	10 9 49.70	+16 30 37.4	n9.427	0.622
29 15 54 50	27	5	+1 33.26	— 9 39.8	10 5 34.91	+18 31 50.8	n9.414	0.593
30 15 46 27	28	5	—1 47.01	+ 2 43.6	10 4 31.86	+19 15 45.5	n9.424	0.584
Feb. 1 15 59 6	29	4	+3 15.31	— 6 41.1	10 2 17.58	+20 20 23.0	n9.360	0.556
28 14 10 51	30	5	—1 20.12	—11 33.8	9 33 41.73	+31 35 16.4	n9.297	0.279
Mar. 1 12 53 26	31	5	+2 15.09	+ 6 51.6	9 32 54.82	+31 51 30.9	n9.529	0.387
7 13 45 55	32	7	+0 53.36	— 6 13.7	9 28 21.22	+33 24 18.4	n9.277	0.199

Mean Places of Comparison-Stars for beginning of the Year of Observation.

*	α	Red. to app. place	δ	Red. to app. place.	Authority
	h m s	s	° ′ ″	″	
1	10 17 18.18	+0.86	+30 11 16.2	— 7.3	Weisse's Bessel X, 303
2	12 56 2.21	+0.06	+22 22 12.7	— 3.9	Bonner Beobb. VI, 22°2536
3	13 7 41.24	+0.08	+21 36 8.7	— 3.5	Weisse's Bessel XIII, 97
4	13 43 55.11	+0.14	+18 15 19.0	— 2.5	" " XIII, 897
5	17 1 36.67	—1.78	— 2 7 0.9	+ 4.8	Schjellerup 6098,9
6	17 16 51.42	—1.67	— 3 37 18.9	+ 3.7	" 6201,2
7	5 34 16.73	+2.49	+ 3 37 14.1	+ 2.8	Weisse's Bessel V, 823
8	5 31 57.58	+2.51	+ 3 15 22.8	+ 3.2	" " V, 749
9	5 27 15.30	+2.53	+ 2 4 21.6	+ 3.6	" " V, 625
10	5 21 59.72	+2.58	+ 2 41 52.3	+ 3.6	Bonner Beobb. VI, 2°968
11	5 12 55.98	+2.65	+ 1 57 14.0	+ 3.8	7 comp's with B.B. VI, +1°967
12	4 51 37.08	+2.79	+ 0 48 52.6	+ 4.8	Weisse's Bessel IV, 1092
13	4 20 44.20	+2.91	— 0 45 55.9	+ 6.1	" " IV, 395
14	4 11 2.10	+2.93	— 1 25 8.2	+ 6.4	" " IV, 143
15	3 21 7.23	+2.96	— 3 51 35.1	+ 7.7	" " III, 340
16	1 49 12.20	+2.68	— 7 8 28.9	+ 9.0	" " I, 851
17	1 18 42.55	+2.47	— 7 29 59.4	+ 9.4	" " I, 271
18	1 10 38.71	+2.40	— 7 44 24.9	+ 9.1	" " I, 124
19	0 52 51.82	+2.29	— 7 35 22.9	+ 9.3	10 comp's with W.B. O, 948
20	0 49 2.96	+2.25	— 7 50 49.7	+ 9.3	Weisse's Bessel O, 822
21	0 41 55.86	+2.21	— 7 41 15.0	+ 9.4	7 comp's with Lamont 51
22	0 17 20.61	—1.13	— 7 4 42.1	—10.6	Schjellerup 122
23	23 48 39.05	—1.47	— 6 19 16.4	—10.7	Weisse's Bessel XXIII, 958
24	23 51 27.09	—1.48	— 6 4 23.7	—10.8	" " XXIII, 1016
25	9 44 54.31	+1.16	—14 50 43.9	+ 0.6	" " (1) IX, 947
26	10 10 36.63	+0.40	+16 35 2.9	— 4.8	" " (2) X, 177,8
27	10 4 1.13	+0.52	+18 44 36.0	— 5.4	" " X, 15,6
28	10 6 18.33	+0.54	+19 13 7.4	— 5.5	" " X, 79,80
29	9 59 1.69	+0.58	+20 27 9.6	— 5.5	" " IX, 1209
30	9 35 1.00	+0.85	+31 46 53.2	— 3.0	" " IX, 696
31	9 30 38.89	+0.84	+31 44 42.1	— 2.8	" " IX, 602
32	9 27 27.06	+0.80	+33 30 33.7	— 1.6	" " IX, 534

NOTE ON THE VARIABLE *Y CYGNI*,

BY S. C. CHANDLER.

The existence of the extraordinary irregularities in the period of this star, which were signalized about a year ago (*A. J.*, VIII, 130), has been abundantly verified by my recent observations; which also develop the interesting fact that the period, which increased by nearly two minutes during 1887 and 1888, has since that time, on the contrary, decreased at a similar surprising rate. As nearly as can be estimated, the reversal occurred toward the middle of 1888, the maximum value being about $1^d\ 11^h\ 58^m.5$. The average value during the last twelve months has been about $1^d\ 11^h\ 56^m.7$.

The confirmation of these unexampled changes gives the star a singular interest, and ought to lead to its being diligently followed. Since the inequality is apparently a periodical one, covering only a few hundred periods of the star, its character can be more advantageously determined by observers in northern Europe than it can be here, as the star can be observed there during a much larger portion of the year.

I subjoin an ephemeris based on the provisional elements

$$1889\ \text{Oct.}\ 3^d\ 14^h\ 50^m.0\ (\text{Gr. M.T.}) + 1^d\ 11^h\ 56^m.7\ (E-687)$$

The epoch here given is a normal from the three most recently observed minima, namely:

E	Observed Minimum Camb. M.T.	Wt.	Red. to ⊙
	d h m		m
661	1889 Aug. 25 11 33	2	+5.3
695	Oct. 15 9 38	3	+2.9
697	18 9 19	3	+2.7

The value assumed for the period is the average for the last twelve months. This, while undoubtedly nearly a minute below the actual mean period, serves the purpose of this ephemeris better than the larger value would do; although after a few months it will run more widely astray. Only alternate minima are given, the others occurring in full daylight for the present.

MINIMA OF *Y* CYGNI, GREENWICH M.T.

E	1889	*E*	1889
	d h m		d h m
703	Oct. 27 13 57.2	735	Dec. 14 12 11.6
705	30 13 50.6	737	17 12 5.0
707	Nov. 2 13 41.0	739	20 11 58.4
709	5 13 37.4	741	23 11 51.8
711	8 13 30.8	743	26 11 45.2
713	11 13 24.2	745	29 11 38.6
715	14 13 17.6		1890
717	17 13 11.0	747	Jan. 1 11 32.0
719	20 13 4.4	749	4 11 25.4
721	23 12 57.8	751	7 11 18.8
723	26 12 51.2	753	10 11 12.2
725	29 12 44.6	755	13 11 5.6
727	Dec. 2 12 38.0	757	16 10 59.0
729	5 12 31.1	759	19 10 52.4
731	8 12 24.8	761	22 10 45.8
733	11 12 18.2		

OBSERVATIONS OF COMETS

MADE AT THE U.S. NAVAL OBSERVATORY WITH THE 9.6-INCH EQUATORIAL.

BY PROF. E. FRISBY.

[Communicated by the Superintendent.]

1889 Washington M.T.	*	No. Comp.	☄ — * Δα	☄ — * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
			COMET *e* 1889.					
d h m s			m s	′ ″	h m s	° ′ ″		
Aug. 19 8 58 42.5	1	15 , 3	—2 22.21	+ 0 24.1	15 45 43.82	+18 51 10.6	*n*9.549	0.568
19 8 58 42.5	2	15 , 3	—1 59.58	— 2 15.9	15 45 43.19	+18 54 39.0	*n*9.549	0.568
Sept. 21 9 57 20.7	3	15 , 3	+3 19.99	—11 59.4	16 59 23.11	+30 53 36.6	9.716	0.590
27 9 40 15.7	4	15 , 3	—3 56.93	+ 4 4.3	17 10 31.83	+31 50 11.8	9.667	0.571
28 9 25 25.3	4	10 , 2	—2 5.03	+12 45.4	17 12 26.72	+31 58 53.0	9.710	0.546
			COMET *d* 1889.					
Sept. 21 11 37 6.9	5	20 , 4	—1 56.10	+ 8 12.9	23 53 25.01	— 5 24 9.1	*n*8.126	0.789
27 10 17 57.4	6	20 , 4	+0 7.90	+ 4 58.7	23 49 35.81	— 5 11 55.1	*n*9.103	0.786
28 10 8 24.3	6	20 , 4	—0 28.21	+ 7 31.2	23 48 59.70	— 5 9 22.6	*n*9.132	0.786
Oct. 18 9 31 3.2	7	20 . 4	+2 17.29	+ 1 13.9	23 40 13.38	— 3 54 10.4	*n*8.572	0.777

Mean Places for 1889.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	15 48 5.15	+0.88	+18 54 8.1	+ 8.4	Weisse's Bessel XV, 1163
2	15 50 11.88	+0.89	+18 56 46.5	+ 8.4	Weisse's Bessel XV, 1203
3	16 56 2.63	+0.49	+31 5 23.2	+12.8	$\frac{1}{3}$(Yarnall+2 Grant)
4	17 44 29.89	{ +1.87 } { +1.86 }	+31 45 54.3	{ +13.2 } { +13.3 }	Weisse's Bessel XVII, 367
5	23 55 18.96	+2.45	— 5 32 37.7	+15.7	Yarnall 10604
6	23 19 25.47	+2.44	— 5 17 9.4	+15.6	Weisse's Bessel XXIII, 973
7	23 37 53.68	+2.41	— 3 55 39.7	+15.4	Schjellerup 9800

ELEMENTS OF COMET 1888 III,

By H. V. GUMMERE.

[Communicated by Prof. F. P. Leavenworth.]

The elements given below were computed by Mr. H. V. Gummere, from normal places obtained from thirty, thirty-eight, and eighteen observations, respectively. Perturbations by the planets were not considered. All other corrections were applied.

Normal Places.

1888	α	δ
	h m s	° ′ ″
Aug. 10.0	10 26 44.40	+44 50 38.2
Sept. 5.0	13 36 19.80	+34 0 57.9
Oct. 1.0	15 32 20.87	+14 27 30.9

Haverford College, Pa.

Elements.

$T =$ 1888 July 31.135067 Gr. M.T.

$$\left.\begin{array}{rl} \omega = & 59^\circ\ 12'\ 3''.78 \\ \Omega = & 101\ \ 29\ \ 45\ .80 \\ i = & 71\ \ 11\ \ 42\ .20 \end{array}\right\} 1888.0$$

$\log q = 9.9553124$

Middle place, (O—C):

$\Delta\lambda \cos\beta = -0''.07, \quad \Delta\beta = -0''.85.$

ELEMENTS AND EPHEMERIS OF COMET *b* 1889,

By W. W. CAMPBELL.

From a normal place for April 25 (see *Astr. Journ.* 197) and Ann Arbor observations of July 25 and October 23, I have computed new elements and continued the ephemeris of this comet.

Elements.

$T =$ 1889 June 10^d.8250 Gr. M.T.

$$\left.\begin{array}{rl} \omega = & 236^\circ\ \ 6'\ \ 2''.9 \\ \Omega = & 310\ \ 42\ \ \ 9\ .4 \\ i = & 163\ \ 50\ \ 30\ .8 \end{array}\right\} \begin{array}{l}\text{Ecliptic and Mean} \\ \text{Equinox 1889.0}\end{array}$$

$\log q = 0.353318$

Residuals (O—C), $\cos\beta'\Delta\lambda' = -0''.8, \quad \Delta\beta' = +0''.4$

Equatorial Coordinates.

$$x = [9.990114]\, r \sin [v + 14^\circ\ 15'\ 12''.2]$$
$$y = [9.989645]\, r \sin [v + 101\ \ 31\ \ \ 9.8]$$
$$z = [9.479705]\, r \sin [v + 147\ \ 14\ \ 21.9]$$

Ephemeris for Greenwich Mean Time.

1889	α	δ	log r	log Δ	Br.
	h m s	° ′			
Nov. 2.5	1 21 13	—15 58.2	0.4441	0.2821	1.32
4.5	1 14 37	16 16.1	0.4460	0.2895	
6.5	1 8 16	16 31.7	0.4480	0.2974	1.21
8.5	1 2 12	16 45.0	0.4500	0.3056	
10.5	0 56 24	16 56.2	0.4520	0.3140	1.10
12.5	0 50 53	17 5.4	0.4540	0.3227	
14.5	0 45 39	17 12.7	0.4560	0.3315	0.99
16.5	0 40 41	17 18.3	0.4580	0.3405	
18.5	0 36 1	17 22.4	0.4600	0.3495	0.90
20.5	0 31 36	17 25.0	0.4621	0.3586	
22.5	0 27 28	17 26.3	0.4641	0.3678	0.81
24.5	0 23 35	17 26.4	0.4661	0.3770	
26.5	0 19 56	17 25.4	0.4681	0.3862	0.73
28.5	0 16 32	17 23.4	0.4701	0.3953	
30.5	0 13 22	17 20.5	0.4722	0.4043	0.66
Dec. 2.5	0 10 25	17 16.8	0.4742	0.4132	

ON A NEW VARIABLE STAR IN *HYDRA*,

$\alpha = 13^h\ 41^m\ 59^s, \quad \delta = -27^\circ\ 44'.5$ (1875.0)

By EDWIN F. SAWYER.

In a sequence observed on 1884 May 17, the star 358 (*U.A.*) *Hydrae* (the magnitude of which is given as 7.0 from the observations at Cordoba) apparently occurs, and was noted as faint and equal 7^M.3. Its position was also found to be not in accord with the Cordoba position on the chart. Observations at various times during the years 1885 and 1886 invariably found the star faint, and about 7^M.4 or 7^M.5. In mentioning the matter to Dr. Gould, he suggested that perhaps the wrong star had been observed. A chart of the stars in the vicinity of the suspected variable was made from the Cordoba General Catalogue, and it was at once seen that the star numbered 18,788 of the General Catalogue, of 7^M.4 (which lies very close to the position of the star 358 (*U.A.*) *Hydrae*) had invariably been observed, and that the star 358 had not once been seen. The discordance in the position noted above was also explained.

The star was looked for on 1888 March 17, and estimated as 8^M.0. Observations on April 4 and 6 apparently showed a slight decrease, but not certain enough to warrant an announcement of discovery, a course of proceeding unfortunately too often practised by some observers.

On the morning of March 7 of the present year, the star was again looked for, and all doubts as to its variability were at once removed, the star appearing bright, 7^M.2, and evidently near maximum. It was observed until May 28, on which date it had faded more than a unit of magnitude.

I find the following data in reference to the new variable: It was observed by Argelander, 1851 May 20, as 8^M. (Zone

383, No. 54.) It was also observed twice in Washington zones, as follows: 1846 June 3 as $7^M.8$, with Meridian circle; and 1847 May 29 as 7^M, with the Mural circle. It was observed in **Gould**'s zones 1875 May 24, as 7^M, and also observed four times in 1875 for his General Catalogue, being estimated as $6\frac{3}{4}^M$ and 7^M, on June 28 and 29, respectively. An inspection of the meagre data indicates that the period may prove to be about one year. The star is quite red.

ELEMENTS AND EPHEMERIS OF COMET *d* 1889.

By S. C. CHANDLER.

Gr.M.T. 1889	App. α h m s	App. δ ° ′	log *r*	log Δ	Br.
Nov. 1.5	23 41 17	—2 28.2	0.2930	0.0543	1.80
2.5	41 33	2 21.2			
3.5	41 51	2 13.9			
4.5	42 12	2 6.6			
5.5	42 33	1 59.1	0.2940	0.0671	1.69
6.5	42 57	1 51.5			
7.5	43 23	1 43.8			
8.5	43 50	1 36.0			
9.5	44 19	1 28.0	0.2952	0.0804	1.59
10.5	44 49	1 20.0			
11.5	45 22	1 11.8			
12.5	45 55	1 3.6			
13.5	46 31	0 55.2	0.2965	0.0939	1.48
14.5	47 8	0 46.8			
15.5	47 47	0 38.2			
16.5	48 28	0 29.6			
17.5	49 10	0 20.8	0.2978	0.1077	1.38
18.5	49 53	0 12.0			
Nov. 19.5	50 38	—0 3.0			

The above ephemeris is computed from the elements

$$
\begin{aligned}
T &= 1889 \text{ October } 2.1112 \text{ Gr. M.T.} \\
\omega &= 344^\circ\ 29'\ 20''.6 \\
\Omega &= 17\ \ 52\ \ 19\ .0 \\
i &= 6\ \ 5\ \ 6\ .9
\end{aligned}
\Bigg\}\ 1889.0
$$

$$
\begin{aligned}
\varphi &= 28\ \ \ 2\ \ 11\ .6 \\
\log a &= 0.565011 \\
\text{Period} &= 7.039 \text{ years}
\end{aligned}
$$

The first ellipses calculated for this comet placed the aphelion in the neighborhood of *Jupiter's* orbit, as was noted by the Rev. G. M. **Searle** in a private letter, at the time; but were of course too inexact to give any idea of the real relation of the two paths near their points of approach. The present orbit, however, permits this to be effectively inquired into, and the result is extremely interesting.

The descending node of the comet's orbit upon that of *Jupiter* lies at 185°.5 longitude, *Jupiter's* aphelion at 191° and the comet's aphelion at 183°. The aphelion distances are 5.4541 and 5.3992, respectively, the mutual inclination of the orbits is 3°.0, and the orbital velocities nearly the same. Consequently when both bodies happen to be near this region they remain together many months. A remarkably close approach occurred 1886 May 16.5, when they were in conjunction at heliocentric longitude 185° 20′.8, the difference of heliocentric latitude being but 1′.1, and that of the radii vectores but 0.061. Their mutual distance was therefore only 0.064 at that point, and for more than a hundred days, from the last of March to the middle of July, it did not exceed 0.100. While a nicer determination of the elements will be necessary to settle the exact conditions, it is probable that the character of the orbit was radically changed during the appulse.

ELEMENTS AND EPHEMERIS OF COMET *e* 1889 (*DAVIDSON*).

By WILLIAM BELLAMY.

The ephemeris published in *Astr. Journ.* 201 appearing to hold good, I have continued it to December 5, and give the elements from which it was derived. They were computed from the same positions as those first given, but corrected for aberration and parallax, and accord very closely with those afterwards obtained by Prof. **Safford** from three other positions at longer intervals, which were published in *Astr. Journ.* 202.

$$
\begin{aligned}
T &= 1889 \text{ July } 19.2977 \text{ Gr. M.T.} \\
\omega &= 345^\circ\ 53'\ 20'' \\
\Omega &= 286\ \ \ 8\ \ 23 \\
i &= 66\ \ \ 0\ \ 41
\end{aligned}
\Bigg\}\ 1889.0
$$

$$\log q = 0.016986$$

$$(\mathrm{C-O}),\quad \Delta\lambda\cos\beta = +15'',\quad \Delta\beta = -2''$$

Equatorial Coordinates.

$$
\begin{aligned}
x &= r\,[9.68066]\sin\,[v+21^\circ\ 19'\ 56''] \\
y &= r\,[9.96320]\sin\,[v+239\ \ 27\ \ 10] \\
z &= r\,[9.98333]\sin\,[v+322\ \ 28\ \ 52]
\end{aligned}
$$

Ephemeris for Geenwich Time.

1889	α h m s	δ ° ′	log *r*	log Δ	Br.
Oct. 30.5	18 14 26	+35 37	0.2843	0.2885	0.10
Nov. 1.5	18 29	35 49	0.2896	0.2919	
3.5	22 33	36 1	0.2949	0.3013	0.09
5.5	26 38	14	0.3001	0.3075	
7.5	30 45	27	0.3053	0.3137	0.08
9.5	34 53	39	0.3104	0.3197	
11.5	39 2	36 52	0.3154	0.3256	
13.5	43 13	37 5	0.3201	0.3314	0.07
15.5	47 25	18	0.3253	0.3371	
17.5	51 39	32	0.3302	0.3428	
19.5	18 55 53	45	0.3350	0.3483	0.06
21.5	19 0 9	37 59	0.3398	0.3537	
23.5	4 25	38 13	0.3445	0.3591	
25.5	8 43	27	0.3491	0.3641	
27.5	13 1	41	0.3537	0.3697	0.05
29.5	17 21	38 56	0.3583	0.3748	
Dec. 1.5	21 41	39 10	0.3628	0.3799	
3.5	26 3	25	0.3672	0.3850	
5.5	19 30 25	39 40	0.3716	0.3900	0.04

EPHEMERIS OF VARIABLES OF THE *ALGOL*-TYPE,

Approximate Greenwich M.T., 1889.

November	d	h	November	d	h	December	d	h	December	d	h	December	d	h
Algol	1	8	Algol	18	13	*S* Cancri	1	20	Algol	11	11	*R* Can. Maj.	21	12
R Can. Maj.	1	12	*R* Can. Maj.	18	13	Librae	1	23	*Y* Cygni	11	12	Tauri	22	14
R Can. Maj.	2	15	*R* Can. Maj.	19	16	*Y* Cygni	2	12	*U* Coronae	11	17	*R* Can. Maj.	22	15
Y Cygni	2	14	*Y* Cygni	20	13	Tauri	2	20	*R* Can. Maj.	12	9	Librae	22	22
S Cancri	3	9	Algol	21	10	Algol	2	21	*U* Cephei	13	11	Algol	22	23
U Cephei	3	13	*S* Cancri	22	9	*U* Cephei	3	11	*R* Can. Maj.	13	13	*U* Cephei	23	10
Y Cygni	5	14	*U* Cephei	23	12	*R* Can. Maj.	4	10	Algol	14	8	*Y* Cygni	23	12
U Cephei	8	13	*Y* Cygni	23	13	*U* Coronae	4	19	*Y* Cygni	14	12	*R* Can. Maj.	23	18
Y Cygni	8	13	Algol	24	6	*Y* Cygni	5	12	*R* Can. Maj.	14	16	*R* Can. Maj.	24	21
R Can. Maj.	9	11	Tauri	24	22	*R* Can. Maj.	5	14	Tauri	14	17	*U* Coronae	25	12
R Can. Maj.	10	14	*R* Can. Maj.	25	8	Algol	5	18	*R* Can. Maj.	15	19	Algol	25	19
Y Cygni	11	13	*R* Can. Maj.	26	12	*R* Can. Maj.	6	17	Librae	15	22	*Y* Cygni	26	11
R Can. Maj.	11	17	*Y* Cygni	26	13	Tauri	6	19	Algol	17	5	Tauri	26	13
Algol	12	19	*R* Can. Maj.	27	15	*R* Can. Maj.	7	20	*Y* Cygni	17	12	*U* Cephei	28	10
S Cancri	12	21	*U* Coronae	27	21	*U* Cephei	8	11	*U* Cephei	18	10	Algol	28	16
U Cephei	13	13	*U* Cephei	28	12	*Y* Cygni	8	12	*U* Coronae	18	14	*Y* Cygni	29	11
Y Cygni	14	13	*R* Can. Maj.	28	19	Algol	8	14	Tauri	18	16	Librae	29	21
Algol	15	16	Tauri	28	21	Librae	8	22	*R* Can. Maj.	20	8	*S* Cancri	30	7
R Can. Maj.	17	10	*Y* Cygni	29	13	Tauri	10	18	*Y* Cygni	20	12	Tauri	30	12
Y Cygni	17	13	*R* Can. Maj.	29	22	*S* Cancri	11	8	*S* Cancri	20	20	Algol	31	13
U Cephei	18	12												

OCCULTATION OF *JUPITER*, 1889 SEPTEMBER 3,

BY EDWIN F. SAWYER.

The low altitude of the moon at the time of occultation, together with a very hazy state of the sky, prevented all but the last contact at immersion being well observed; this phase, however, being quite accurately noted. My 4⅝ inch CLACEY Equatorial of 44 inches focal length was employed, and a magnifying power of 70 used.

The time was taken by Messrs. ALBERT STORER and CHAS. W. MEAD, the former using chronometer 2703, by JOHN BLISS & Co., of New York, and beating half-seconds, the latter a fine pocket timepiece, which had been compared with the chronometer just previous to the occultation and found to be 28ˢ.8 fast. From these the following Greenwich M.T. was obtained:

Chronometer 2703,	14ʰ 54ᵐ 32ˢ.7
Hourly rate +0ˢ.12,	— 0.8
Hence,	14 54 31.9
Watch,	14 55 2.0
Watch fast,	—28.8
Hourly rate same as chronometer,	— 0.8
Hence,	14 54 32.4
Mean,	14ʰ 54ᵐ 32ˢ.15

The approximate position of observatory is

Longitude 4ʰ 44ᵐ 34ˢ.5 Latitude 42° 20′ 43″.5.

Brighton, Mass., 1889 *October* 5.

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ON THE PERIOD OF *U CORONAE*.

By S. C. CHANDLER.

Of the series of investigations upon the periods of the stars of the *Algol*-type, three have already appeared, to wit, *Algol*, *U Ophiuchi* and *U Cephei*; and a fourth is here presented, *U Coronae*. In this star, also, I find satisfactory proof of an inequality of period, of the same order as those detected in *U Ophiuchi* and *U Cephei*. The period is shortening by $0^s.0036$ from minimum to minimum; the adopted elements being

$$1870 \text{ March } 25^d\ 10^h\ 38^m.5 \text{ (Greenwich M.T.)}$$
$$+\ 3^d\ 10^h\ 51^m\ 12^s.4\ E - 0^s.0018\ E^2$$

These results depend upon forty-five minima, very unequally distributed. Two of them are inferred from isolated observations at Bonn and Pulkowa, in 1856, 1862 and 1863. Of the regularly observed minima, thirty-eight lie in the interval 1870-1874, while the remaining five are scattered over the past fifteen years. The star has been deplorably neglected. Several other minima have, indeed, been determined at Strassburg, by WINNECKE and HARTWIG, since 1877, but the results have not yet been published, so far as I know.

Previous to the discovery of its variability, the star was noted on various occasions, as follows:

1828 May $20^d\ 11^h\ 20^m$ Königs. M.T., BESSEL estimated it as 8^M, hence it was probably near its maximum brightness. The nearest epoch by the elements above given ($E = -4427$) falls about twelve hours later; the observation is therefore of no service.

1856 April $1^d\ 13^h\ 30^m$ Bonn M.T., SCHÖNFELD passed over the region without noting the star, in DM. zone 905 (*Gränzzone*); and ARGELANDER therefrom concludes that it was not then bright, as there was plenty of time, and other stars farther from the limits were recorded. As a minimum (—1179) actually fell on this evening, this observation may properly be treated as roughly denoting its time. Both WINNECKE and SCHÖNFELD have so used it, and I follow their precedent.

1862 October $6^d\ 8^h.0$ Pulk. M.T., WINNECKE made a note that the star was faint, while observing its neighbor, *S Coronae*. Also on 1863 August $2^d\ 12^h.5$ Pulk. M.T., he made comparisons which show its brightness to have been below 7 of his light-scale. Minima fell on both these evenings, —790 on the first and —703 on the second; we can therefore combine the data to assign a time of minimum for a middle epoch, say —746, 1863 March 7. Thus, adding and subtracting appropriate multiples of the period, assuming plausible reductions to minimum from the light-curve given by WINNECKE, and applying light-equations, we have the heliocentric Pulkowa time of minimum,

from 1st obs., 1863 Mar. $7^d\ 5^h\ 30^m\ -1^h\ 30^m = 4^h\ 0^m$
" 2d " $1\ \ 43\ \ +1\ \ 30\ = 3\ \ 16$

the mean of which referred to Greenwich geocentric M.T. is the value entered in the table of minima below.

The other minima in the table are used exactly as published, as we do not yet possess the means of reducing them homogeneously. In the case of WINNECKE and SCHÖNFELD, eight minima observed in common give a difference

$$S - W = +8^m.2 \quad \pm 4^m.7,$$

the mean being taken without regard to weights. There is little reason, then, to fear personal constant difference, in the case of these observers, much exceeding the accidental errors.

Column I of (O—C) gives the deviations from the elements of SCHÖNFELD's Catalogue, which will represent the observations down to 1873, after which a rapidly widening divergence sets in, amounting to about three hours at the present time. In column II are the deviations from the elements of my catalogue. The differences from 1870 to 1889 are here all of moderate amount, but have a decided systematic character, which, taken in connection with the large negative values for 1856 and 1863, points to the necessity of a quadratic term.

Condensing the table into six normal epochs we have:

TABLE OF MINIMA.

Epoch	Observed Minimum Greenwich M.T.					Red. to ⊙	(O—C)			p	Observer
			d	h	m	m	I m	II m	III m		
−1479	1856	Apr.	1	13	1.7	+5.2	— 12.5	—170.9	— 6.5	½	DM. Obs.
— 746	1863	Mar.	7	1	33.0	+3.8	+ 16.0	—69.1	— 0.2	½	Winnecke
0	1870	Mar.	25	10	56.2	+4.9	+ 33.0	+22.5	+17.5	1	Schönfeld
0			25	10	26.4	+4.9	+ 3.2	— 7.3	— 2.3	2	Winnecke
+ 18		May	26	13	33.2	+4.8	— 12.5	—21.2	—17.3	1	Schönfeld
20		June	2	11	34.4	+4.4	+ 5.8	— 2.7	+ 1.0	2	Winnecke
20			2	11	39.2	+4.4	+ 10.6	+ 2.1	+ 5.8	3	Schönfeld
22			9	9	16.4	+4.0	+ 4.9	— 3.4	+ 0.2	2	Winnecke
29		July	3	13	3.4	+2.1	— 8.7	—16.3	—13.1	1	"
31			10	11	0.4	+1.4	+ 5.1	— 2.3	+ 0.8	3	"
31			10	10	47.2	+1.4	— 8.1	—15.5	—12.5	3	Schönfeld
42		Aug.	17	10	23.9	—2.1	+ 1.4	— 4.9	— 2.5	3	Winnecke
53		Sept.	24	9	31.7	—4.8	— 17.2	—22.4	—20.7	1	"
55		Oct.	1	7	34.2	—5.1	+ 2.6	— 2.4	— 0.8	3	Schönfeld
66		Nov.	8	6	52.2	—5.4	— 3.4	— 7.3	— 6.3	½	"
66			8	7	7.1	—5.4	+ 11.5	+ 7.6	+ 8.6	½	Winnecke
100	1871	Mar.	5	15	25.9	+3.7	— 22.9	—23.4	—24.4	2	"
102			12	13	5.3	+4.2	— 25.5	—25.8	—26.9	3	"
102			12	13	44.2	+4.2	+ 13.4	+13.1	+12.0	3	Schönfeld
106			26	8	54.4	+5.0	— 0.6	— 0.5	— 1.9	2	Wijkander
106			26	8	53.3	+5.0	— 1.6	— 1.5	— 2.9	2	Dunér
106			26	8	58.0	+5.0	+ 3.1	+ 3.2	+ 1.8	3	Schmidt
115		Apr.	26	10	38.9	+5.6	+ 3.4	+ 4.4	+ 2.5	3	"
117		May	3	8	27.7	+5.6	+ 9.7	+10.9	+ 8.9	3	"
117			3	8	6.2	+5.6	— 11.8	—10.6	—12.6	1	Schönfeld
117			3	7	57.0	+5.6	— 21.0	—19.8	—21.8	½	Winnecke
135		July	4	11	29.0	+2.0	— 15.0	—12.0	—15.6	1	"
146		Aug.	11	10	59.0	—1.5	— 12.2	— 8.1	—11.7	2	"
146			11	10	52.2	—1.5	— 19.0	—14.9	—18.5	3	Schönfeld
148			18	9	11.2	—2.1	+ 16.9	+21.2	+17.5	1	"
148			18	8	53.2	—2.1	— 1.1	+ 3.4	— 0.3	½	Winnecke
212	1872	Mar.	26	7	38.2	+5.0	+ 11.5	+22.2	+15.1	2	Schönfeld
221		Apr.	26	9	14.2	+5.6	+ 6.9	+18.5	+11.0	3	"
252		Aug.	11	9	52.2	—1.6	+ 9.1	+23.8	+14.8	3	"
345	1873	June	28	10	55.2	+2.5	— 9.4	+14.4	+ 1.1	3	"
414	1874	Feb.	21	15	43.2	+2.8	— 12.1	+18.8	+ 2.7	2½	"
427		Apr.	7	12	42.2	+5.4	— 16.7	+15.5	— 1.1	3	"
431			21	8	2.2	+5.6	— 21.4	+11.2	— 5.5	1	"
449		June	22	11	47.2	+3.0	— 6.2	+28.2	+10.8	3	"
460		July	30	11	9.2	—0.4	— 11.3	+24.2	+ 6.5	3	"
1088	1880	July	6	9	57.7	+1.8	—101.4	— 3.1	—31.5	3	Schmidt
1099		Aug.	13	9	38.9	—1.7	— 87.4	+12.0	—16.3	3	"
1942	1888	Aug.	1	13	58.5	—0.7	—184.9	— 1.2	— 6.1	3	Chandler
2026	1889	May	18	14	4.0	+4.5	—158.6	+33.5	+33.4	1	Yendell
2035		June	18	15	3.8	+3.3	—201.2	— 8.2	— 7.8	2	"

	Minima included	Mean Epoch	(O—C) I	(O—C) II	(O—C) III
			m	m	m
I		—1479	— 12.5	—170.9	— 6.5
II		— 746	+ 16.0	— 69.1	— 0.2
III	0– 148	+ 77	— 1.4	— 4.2	— 3.9
IV	212– 460	356	— 4.7	+ 20.3	+ 6.6
V	1088–1099	1093	— 94.4	+ 4.5	—23.8
VI	1942–2035	+1987	—186.0	+ 2.2	+ 0.1

From the differences we find the values of the period for various epochs in the "observed" column below. In the "computed" column are the values, for comparison, of the finally adopted period

$$3^d\ 10^h\ 51^m\ 12^s.4 - 0^s.0036\ E$$

	Epoch	Observed	Computed	O—C
		d h m s	s	s
I - II	—1112	3 10 51 16.93	16.40	+0.53
II -III	— 324	13.33	13.57	—0.24
III- IV	+ 217	13.88	11.58	+2.30
IV - V	+ 725	7.31	9.79	—2.48
V -VI	+1539	8.46	7.86	+0.60

While the numerical sequence of the observed periods is not entirely regular, it sufficiently justifies the assumption of a shortening of the period.

Column III of (O—C) gives the deviations from the finally adopted elements, already given near the beginning of this paper. The residuals are quite satisfactory, and a more refined least-square solution would scarcely lead to any practical improvement. We find from them the probable error of a completely satisfactory observation of minimum $(p=3)$ $\pm 7^{m}.4$; and of one of average goodness $(p=2)$ $\pm 9^{m}.4$. From the eight minima observed in common by SCHÖNFELD and WINNECKE, the probable error of a minimum by a single observer is $\pm 9^{m}.1$ (p about 2), almost identical with the above result. So far as this goes it shows that the adopted hypothesis is conformable within the limits of the purely accidental errors of the observations.

Cambridge, 1889 *October* 24.

SUN-SPOT OBSERVATIONS, FEBRUARY TO NOVEMBER, 1889,

BY PAUL S. YENDELL.

The subjoined observations are in continuation of the series published in this Journal. Vol. VIII. pp. 117 and 160. The conditions of observation remain unchanged. The series has suffered much interruption from unfavorable weather during the summer and autumn.

Date	Time	Gps.	Sps.	Date	Time	Gps.	Sps.	Date	Time	Gps.	Sps.	Date	Time	Gps.	Sps.
1889	h m			1889	h m			1889	h m			1889	h m		
Feb. 3	21 15	0	0	Apr. 14	20 45	0	0	June 13	20 25	0	0	Aug. 20	20 30	0	0
5	21 50	0	0	15	20 15	0	0	17	20 35	1	4	21	20 35	0	0
6	20 45	0	0	18	20 30	0	0	18	20 45	1	11	25	20 45	0	0
10	21 5	0	0	19	20 30	0	0	19	20 45	1	6	26	21 15	1	1
12	20 30	0	0	22	20 30	0	0	20	20 25	1	5	27	20 30	1	1
13	20 30	0	0	23	20 30	0	0	23	20 30	1	4	28	22 15	1	1
14	20 45	0	0	24	20 45	0	0	24	20 30	1	1				
15	20 45	0	0	26	20 45	0	0	26	21 5	1	1	Sept. 1	20 30	1	1
18	20 35	0	0	28	20 45	0	0	27	20 30	0	0	2	20 30	1	1
19	20 30	0	0	29	20 45	0	0	28	20 35	0	0	3	20 40	1	1
20	20 30	0	0	30	20 45	0	0					4	20 45	1	1
22	20 30	0	0					July 1	20 30	0	0	5	20 30	1	1
25	22 15	0	0	May 1	20 45	0	0	5	20 35	0	0	15	21 35	0	0
28	20 30	0	0	3	20 35	0	0	8	20 30	0	0	19	20 45	0	0
				5	20 25	1	1	11	20 30	2	2	20	20 45	0	0
Mar. 1	20 15	0	0	6	20 55	1	3	12	20 30	1	1	22	20 25	0	0
6	20 35	0	0	7	20 25	1	4	15	20 30	2	10	23	20 45	1	5
8	20 45	0	0	8	20 15	1	4	17	20 30	2	8	26	20 45	1	3
10	21 45	0	0	9	20 55	1	5	18	20 30	1	7	26	21 15	1	4
13	21 15	2	5+	12	20 30	0	0	21	20 30	1	1	27	20 30	1	3
21	20 15	0	0	13	21 0	0	0	22	20 30	1	1	30	20 45	1	2
22	22 30	0	0	15	20 30	0	0	23	20 25	1	1				
24	21 0	0	0	16	20 40	0	0	24	20 30	0	0	Oct. 1	20 45	1	3
25	20 30	0	0	17	20 35	0	0	25	20 30	1	3	2	20 30	1	1
26	20 30	0	0	21	20 35	0	0	28	20 35	3	9	3	20 45	1	1
28	20 15	0	0	22	21 15	0	0	30	20 45	1	11	7	20 45	0	0
29	20 30	0	0	23	20 45	0	0					8	20 30	0	0
				24	20 25	0	0	Aug. 5	20 30	1	19	10	20 30	0	0
Apr. 2	20 30	0	0	26	20 30	0	0	6	20 30	1	22	11	20 35	0	0
5	22 15	1	1	28	20 45	0	0	7	20 25	1	11	14	20 45	0	0
7	20 30	1	1					9	20 30	3	19	15	20 45	0	0
9	20 30	0	0	June 5	20 45	0	0	11	20 30	2	7	16	21 0	0	0
10	20 30	0	0	6	20 45	0	0	15	20 30	2	5	17	21 0	0	0
11	20 30	0	0	10	20 45	0	0	16	20 30	1	1	21	20 30	0	0
12	22 15	0	0	11	20 15	0	0	18	20 30	1	1	22	20 15	0	0
13	21 15	0	0	12	20 30	0	0	19	20 45	0	0	25	21 30	0	0

NOTES.

Feb. 3. Seeing pretty bad. — Feb. 5. Thin cloud but fair seeing. — Feb. 6. Seeing poor. — Feb. 10. Seeing fair. — Feb. 12. Seeing poor. — Feb. 13. Seeing fair. — Feb. 14. Air rather tremulous. — Feb. 19. Seeing good; careful observation. — Feb. 23. Seeing very bad; therm. outside +7°. — Feb. 25. Seeing fair. — Feb. 28 and Mar. 1. Seeing good. — Mar. 6. Thin cloud, but definition sharp and steady. — Mar. 8. Very poor; through snow-cloud. — Mar. 10. Rather tremulous. — Mar 14. Seeing poor; outlying small spots could not be counted; one of the large ones probably again subdivided. — Mar. 21. Definition sharp and clear. — April 2. Slightly hazy, but very good definition. — April 27 and 29. Hazy. — April 30. Seeing very bad. — May 5. Seeing perfect; large group of faculae accompanying spot. — May 6. Opening in heavy fog; seeing exceedingly sharp and clear; large and bright group of faculae *f* spot-group. — May 7. Thin fog; seeing sharp; same group of faculae. — May 8. Same group of spots; disappearing. — May 9. Same group; seeing perfect. — May 13. Seeing perfect. — June 18. Same group as on 17; one large spot followed by cluster of small ones. — June 21. The large spot first seen 17th; umbra has divided into two; small spots following appear to have closed up. — June 26. Same large spot, now very near limb. — July 13. One large spot. — July 22. Large spot surrounded by faculae to such an extent as to make the whole neighborhood appear as a spot markedly brighter than the limb about it. — July 25. Seeing poor; thin cloud and halo. — July 28. Flying clouds and mist. — July 30. Large and bright group of faculae near *pr* limb. — Aug. 9. Preceding group surrounded by wide and bright faculae. — Aug. 18. Surrounded by faculae. — Aug. 26. Large spot followed by bright faculae; near *f* limb. — Aug. 27. Same spot. — Sept. 23. Close to limb; surrounded with bright faculae; air unsteady. — Sept. 26, $20^h 45^m$. Seeing extremely bad. — $21^h 15^m$. Seeing settled; very fair. — Sept. 28. Seeing rather poor; fair moments. — Oct. 3. Near *pr* limb; accompanied by scattered group of bright faculae.

Boston, 1889 *October* 31.

OBSERVATIONS OF COMET *e* 1888 (*1889 I*),

MADE AT THE HAVERFORD COLLEGE OBSERVATORY,

BY F. P. LEAVENWORTH.

1889 Haverford M.T.	*	No. Comp.	☄ — *		☄'s apparent		log $p\Delta$	
			$\Delta\alpha$	$\Delta\delta$	α	δ	for α	for δ
d h m s			m s	′ ″	h m s	° ′ ″		
June 6 14 17 55	1	9	—1 39.72	—18 3.9	22 45 14.96	+ 2 39 42.6	*n*9.546	0.727
27 12 50 4		6	+3 56.46	— 8 40.6				
July 4 11 49 55	2	7	—0 35.31	+10 42.2	21 31 25.13	+ 0 56 19.1	*n*9.481	0.746
6 12 56 22	3	16 , 5	+0 40.17	+ 1 56.5	21 24 24.57	+ 0 41 28.1	*n*9.221	0.747
27 11 28 54		7	—1 2.10	— 9 34.9				
Sept. 27 8 10 28	4	10 , 3	+0 33.02	— 2 15.4	18 16 57.22	—10 24 47.4	9.425	0.817
28 7 38 11	4	20 , 6	+0 8.64	— 6 6.9	18 16 32.84	—10 28 38.9	9.341	0.723

Mean Places for 1889.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	22 46 54.28	+0.40	+ 2 57 47.0	—0.5	Schjellerup 9372
2	21 31 58.86	+1.58	+ 0 46 0.9	+6.0	Lamont 8424
3	21 23 42.75	+1.65	+ 0 39 25.3	+6.3	Lamont 8325
4	18 16 22.96	+1.24	—10 22 40.9	+8.9	Lamont 2380

The observations on July 6, September 27 and 28, were made with a filar micrometer; the other observations were made with a square-bar micrometer. On September 27 and 28 the comet was barely visible. I am indebted to S. J. LEUCHNER for positions of comparison-stars.

Haverford College, Pa., 1889 *October*.

ON THE ACTION OF *JUPITER* IN 1886 UPON COMET *d* 1889, AND THE IDENTITY OF THE LATTER WITH LEXELL'S COMET OF 1770.

BY S. C. CHANDLER.

Since the publication of the note in No. 204 of the Journal, I have thought it might be instructive to examine, as well as the present means will permit, the question of the nature of the perturbations suffered by this comet during the appulse to which attention was there drawn. The event has fully justified the anticipation, for such calculations as time has permitted me to make seem to point to the solution of the enigma which has excited higher interest, perhaps, than any problem in cometary astronomy during the last hundred years — namely, that of the fate of LEXELL's comet, which it was feared had been lost to our solar system by the disturbance of *Jupiter* in 1779. While I naturally hesitate to publish conclusions so singular as those to which the investigation has led, until they can be more carefully verified and made more precise, it seems, on the other hand, best to communicate them, even in an imperfect shape, that observers may be incited to give more attention to this object — which has so far been sadly neglected — since the perfecting of its theory will demand the most assiduous observation during the brief remaining interval of its visibility.

Before entering upon the details of the discussion, a summary of the principal conclusions will be given.

First. The encounter with *Jupiter* in 1886 effected a complete transformation of the comet's orbit. Instead of the present small seven years' ellipse, it was previously moving in a large one of twenty-seven years period, whose aphelion lay outside of *Saturn's* orbit, and whose perihelion was almost exactly at the present aphelion distance. The directions of the apsides were reversed, and their line turned through about twenty degrees. The nodes were also reversed, and the line of nodes turned through about nineteen degrees. The plane of the orbit was tilted about fourteen degrees, and the perihelion distance, which is now but slightly greater than *Mars's* aphelion, was then almost precisely that of *Jupiter's* aphelion.

Second. Several months before reaching its perihelion, it passed, near the beginning of 1886, into the sphere of *Jupiter's* attraction, and was deflected into a hyperbolic path about that planet, remaining for more than eight months under its control; the disturbing action of the sun during most of that interval being insignificant. The eccentricity of this hyperbola was but slightly in excess of unity, so that the comet narrowly escaped being drawn into a closed orbit, as a satellite of *Jupiter*.

Third. At the point of closest approach to *Jupiter*, 1886 May 20, the comet was distant from it only about nine diameters of the planet, passing a little outside of the orbit of the third satellite. It is not impossible that the comet may, at some time during its passage through the satellite-system, have got into such a position relative to them or the planet, that the unequal attractions on different portions of its relatively extended volume may have been adequate to produce disruption, and bring about separations of its mass similar to those actually observed during its present apparition, which may, indeed, prove to have had their origin on this occasion.

Fourth. Assuming that the changes in the orbit caused by *Jupiter's* influence, here established, are in the main correct, and that the portion of the perturbations which has been neglected in this first approximation to the solution of the problem, are not sufficient to affect sensibly the mean motion, no previous approach to any planet could have occurred, sufficient appreciably to disturb it, back to the year 1779. In that year, however, the comet must have come so near to *Jupiter* as to pass under his control, and experience a radical change of orbit at the point of longitude where LEXELL's comet underwent its notable disturbance in that year. Moreover, a comparison of the elements of LEXELL's comet, subsequent to that disturbance, with those here found for the present comet previous to 1886, shows a likeness so striking, and entirely within the range of the uncertainty of both, that the only reasonable inference to be drawn, it seems to me, is the identity of the two bodies. The only other alternative — outside, of course, of the rejection of one or both calculations, for uncertainty or incorrectness — is to suppose that two comets met *Jupiter* at the same time and place, and were thrown into similar orbits. The probability of such a hypothesis seems hardly worth considering.

Fifth. The orbit in which the comet is now moving is such that no serious perturbation can occur until 1921, in the spring of which year, however, it will again enter the sphere of *Jupiter's* activity and undergo another violent transmutation. Fortunately at each of the returns, in 1896, 1903, 1910 and 1917, the conditions of visibility will be favorable, so that astronomers will be prepared for the event of 1921 with a well established theory of its motion.

It should be distinctly understood that I regard the particular numerical results of this paper merely as a rude sketch, in the nature of a reconnoissance-survey of the problem. The method pursued takes into account only the principal perturbations by *Jupiter*, that is, from 1886 Jan. 24 to Sept. 14. But for several weeks before and after these limits — which are the points at which I have chosen to transpose *Jupiter* and the sun, as central force and disturbing force, respectively — the ratio of the disturbing to the direct action is by no means inconsiderable, whichever body is treated as the central one. The perturbations during these few weeks, here neglected, will modify materially, but not essentially, the elements given. From considerations into which I will not here enter, I surmise that *Jupiter*, in receding from the comet after September 1886, did not materially displace either the distance (a very critical element) or the longitude, of the aphelion point; also that, while the node may have been shifted a few degrees, the inclination remained approximately the same. Of course any changes here, or in the assumed elements determined from the observations after the disturbance, are seriously magnified in the path relative to *Jupiter*, and reflected in the elements deduced before the appulse. For this reason it was desirable to start the computation with as good an orbit as the available observations would admit. Eight normals were therefore formed, each based on several observed places, covering the interval from July 8 to Oct. 18; and in this connection I desire to express my thanks to the Director and Mr. WENDELL, of the Harvard College Observatory, for unpublished positions.

Instead of varying the extreme distances, I took their ratio and the major axis of the orbit as the unknown quantities to be satisfied by the intermediate normals, as the solution of the equations so formed would afford a measure of the probable error of the critical element of the aphelion distance. When the computation was finished, other observations had come to hand which weakened my confidence in one of the extreme normals, and I modified the plan by employing for the subsequent work of this paper the following interpolated elements.

$$T = 1889 \text{ Sept. } 30.0119 \text{ Gr. M.T.}$$

$$\left.\begin{aligned} \pi &= 1^\circ\ 26'\ 17''.3 \\ \Omega &= 17\ 58\ 45.3 \\ i &= 6\ 4\ 10.5 \end{aligned}\right\} 1890.0$$

$$e = 0.470701$$

$$a = 3.684682$$

$$q = 1.950229$$

$$\text{Period} = 7.0730 \text{ years.}$$

These elements will answer for this first approximation to the perturbative action of *Jupiter*. For this purpose I adopted the simple and unique method of D'ALEMBERT, whose ingenious device for avoiding the great difficulties in calculating perturbations during a close approach of a planet is given in the fifth memoir of the last volume of his collected works (1773). The method has been a little further developed by LAPLACE in the *Mécanique Céleste*, but I have only partially employed the formulas of the latter, keeping to the ecliptic, instead of transferring the coordinates to the plane and major axis of the relative orbit.

We thus have the following hyperbolic orbit in which the comet moved about *Jupiter* between 1886 Jan. 24 and Sept. 14, while traversing the attraction-sphere of the planet. During this interval the action of the sun, as a disturbing body, may be neglected in this first approximation.

Time of passing the perijove,	1886 May 20.7173 Gr. M.T.
Longitude of the perijove,	291° 52′.6
Longitude of the ascending node,	242 20.6
Inclination,	37 55.5
Eccentricity,	1.05796
Semi-transverse axis,	—0.16929
Distance of perijove,	0.00981

These elements are referred to the mean ecliptic and equinox, 1890.0. It will be seen that the nearest distance of the comet was but $\frac{1}{567}$ of its distance from the sun. A remarkable feature of this orbit is the small eccentricity. A slight diminution of the initial velocity relatively to *Jupiter* would have thrown the comet into an elliptic orbit about the planet.

From the coordinates and components of the velocity in this hyperbola, at the time of entering the sphere of *Jupiter's* attraction, we deduce the following orbit, which approximately defines the path which the comet pursued about the sun previous to the disturbance.

$$T = 1886 \text{ Nov. } 28.779 \text{ Gr. M.T.}$$

$$\left.\begin{array}{l}\pi = 203^\circ\ 3'.7\\ \text{☊} = 179\ 13\ .4\\ i = \ \ 7\ 43\ .8\end{array}\right\}1890.0$$

$$e = 0.3947$$

$$a = 8.9896$$

$$q = 5.4411$$

$$\text{Period} = 26.95 \text{ years.}$$

A comparison of these with the elements subsequent to disturbance shows the radical character of the resultant changes.

This orbit confirmed a suspicion which I had previously entertained, of the identity of this object with LEXELL'S comet (1770 II). To examine this question I carried the elements back to 1770.0, as shown in the last column of the following table.

	LEXELL'S comet, after 1779			Comet *d* 1889
	Burckhardt	LeVerrier $\mu = -0.10$	LeVerrier $\mu = +0.35$	before 1886
	° ′	° ′	° ′	° ′
π	301 19	111 0	258 40	201 21
☊	183 15	178 6	175 27	177 34
i	11 42	18 50	11 27	7 43
e	0.178	0.535	0.533	0.395
a	6.388	9.000	9.000	8.990

The values assigned for LEXELL'S comet in this table require explanation. As to BURCKHARDT'S, I cannot find them in any publication of his; and they probably never saw the light except in the incomplete way in which LAPLACE has given them, namely, only the eccentricity and perihelion and mean distances, omitting the three angular elements. I have, therefore, found it necessary to recalculate them, although at the cost of some little trouble, for LAPLACE also neglects to place the proper signs against the coordinates and their differentials.

Under the heading of LEVERRIER I give two sets of elements for two values of his indeterminate μ, answering to the value 9.0 of the semi-axis major of the disturbed orbit; the unit of μ corresponding to an arbitrary change of 0.01 in the semi-axis major of the orbit which the comet had in 1770; the zero from which μ is reckoned being CLAUSEN'S value of that axis. It will be recollected that LEVERRIER, in his discussion of the orbit of this comet, encountered an indeterminateness in the solution of his equations; so that, in fact, various systems of elements could be found which would equally well represent the observations. The differences were small, but assumed importance in considering the character of the subsequent action of *Jupiter* in 1779. He avoided the embarrassment by resigning the attempt to assign absolute values to the elements, and expressed them in terms of the quantity μ, just defined. The elements after the disturbance were also determined as functions of the same arbitrary variable. The process of recognizing the identity of another comet with that of LEXELL consists, then, in ascertaining whether any assumption of the value of μ, in LEVERRIER'S theory, within certain limits, gives elements agreeing substantially with those of the new comet. He gives a table which is a *résumé* of his whole theory, containing the values of the elements for various equidistant values of μ, as an argument. The table given below I have interpolated from this for certain mean distances, selected as hereafter explained. We shall come back to this table presently.

The heliocentric longitudes within which the attraction of the sun was overborne by the influence of *Jupiter* are nearly the same for both comets. Thus we have,

LEXELL'S comet	1767 Jan. 18 – May 9	170° – 178°
" "	1779 May 28 – Oct. 1	178 – 185
Comet *d* 1889	1886 Jan. 24 – Sept. 14	175 – 193

This coincidence was, in fact, what first turned my attention to the subject. But we note still further that, assuming the substantial correctness of the period of comet *d* before disturbance, four periods (107.8 yrs.) are nearly equal to nine of *Jupiter's* (106.9 yrs.). From this it follows that the two bodies must have had another close approach to each other about 1779, when the comet was near its node in longitude 177°.5. This, if it were merely an accidental coincidence with the place and date of the derangement of LEXELL'S comet, would be a very surprising one. But however curious this may be, it might be fairly objected that it does not demonstrate identity, because it implies a much greater precision in the dimensions of the ellipse previous to 1886 than the method I have pursued is capable of. I feel the full force of this, and therefore propose to show that the likeness of the elements to those of LEXELL'S comet still remains, even with very considerable alterations in the major axis.

Whatever the law of the motion of the comet after 1779, it must, if elliptic, return at some time or other to the place of its disturbance. If identical with the present comet, therefore, its period must be an aliquot part of about 107 years. It must be noted that, among the various possible values of the period, $\frac{107}{n}$, we can draw no inference from $n = 3$, inasmuch as this would bring the comet and *Jupiter* together in 1815 and 1850 also, causing enormous perturbations. Similar logical discontinuity attends multiples of 3. The following table contains the elements given by LEVERRIER'S theory for various assumptions, 2, 4, &c., as the number of revolutions between 1779 and 1886. Each of these values results in two possible orbits, corresponding to positive and negative values of the indeterminate μ.

It will be seen that the perihelion longitude changes enormously with μ, practically ranging over the whole circumference. The longitude of the node, however, ranges within quite narrow limits, except for extreme positive values of μ, all near the node of comet *d* before 1886. The inclination of the latter also holds a mean position among those corresponding to positive and moderate values of μ. The eccentricities are all larger than for comet *d*, and indeed, larger than BURCKHARDT obtained for LEXELL'S, but for small values of μ they are not greater than might be expected. On the whole the agreement for $\mu = +0.35$ is the best, and is as satisfactory as could be anticipated from the uncertainty of both determinations.

Rev.	μ	π	☊	i	e	a
		° ′	° ′	° ′		
14	—0.29	27 16	177 53	16 28	0.65	3.86
12	—0.24	38 0	178 2	17 29	0.57	4.28
10	—0.21	47 0	178 6	18 0	0.54	4.82
8	—0.17	61 40	178 5	18 25	0.50	5.61
6	—0.13	110 0	178 6	18 48	0.53	7.05
4	—0.10	110 34	178 6	18 50	0.53	8.90
2	—0.07	126 8	178 2	18 47	0.56	11.14
2	+0.29	240 20	176 0	12 32	0.67	11.14
4	+0.35	259 15	175 26	11 25	0.53	8.90
6	+0.41	278 44	174 46	10 15	0.53	7.05
8	+0.52	302 40	173 14	8 38	0.54	5.61
10	+0.65	319 52	171 55	7 12	0.58	4.82
12	+0.78	328 55	170 10	6 7	0.63	4.28
14	+1.01	337 58	166 57	4 50	0.68	3.86

Taking all the points here presented into consideration there is, to my mind, an overwhelmingly strong presumption in favor of the identity of these two comets. I hope, as soon as the comet disappears, and the observations during its whole apparition are at hand, to proceed to an accurate computation of the whole perturbative effect, of which only the more important parts have here been rudely determined. Meanwhile there are other interesting points to be presented, for which there is not time or space in this communication, and they must be deferred to another number.

Cambridge, 1889 *Nov.* 22.

EPHEMERIS OF COMET *d* 1889.

BY WILLIAM BELLAMY.

Gr. M.T. 1889	App. α	App. δ	log r	log Δ	Br.
	h m s	° ′			
Nov. 24.5	23 54 45	+0 40.5	0.3022	0.1351	1.24
25.5	55 39	49.9			
26.5	56 34	0 59.4			
27.5	57 30	1 9.0	0.3035	0.1457	
28.5	58 28	18.6			
29.5	23 59 27	28.4			
30.5	0 0 27	38.2	0.3048	0.1563	
Dec. 1.5	1 28	48.1			
2.5	2 31	1 58.0			
3.5	3 34	2 8.1	0.3062	0.1668	1.06
4.5	4 39	18.1			
5.5	5 45	28.3			
6.5	0 6 52	+2 38.5	0.3077	0.1774	
Dec. 7.5	0 8 0	+2 48.8			
8.5	9 10	2 59.1			
9.5	10 20	3 9.5	0.3092	0.1879	
10.5	11 32	19.9			
11.5	12 44	30.1			
12.5	13 58	3 40.9	0.3107	0.1983	0.90
13.5	15 12	3 51.5			
14.5	16 28	4 2.1			
15.5	17 44	12.8	0.3123	0.2086	
16.5	19 4	23.5			
17.5	20 19	34.3			
18.5	21 38	45.1	0.3140	0.2189	
19.5	0 22 58	+4 55.9			

Gr. M.T.	App. α	App. δ	log r	log Δ	Br.
	h m s	° ′			
Dec. 20.5	0 24 18	+5 6.8			
21.5	25 40	17.7	0.3157	0.2291	0.79
22.5	27 2	28.7			
23.5	28 45	39.7			
24.5	29 49	5 50.7	0.3174	0.2391	
25.5	0 31 14	+6 1.7			
Dec. 26.5	0 32 39	+6 12.8			
27.5	34 5	23.9	0.3192	0.2491	
28.5	35 32	35.4			
29.5	36 59	46.2			
30.5	0 38 27	+6 57.4	0.3210	0.2589	0.67

This ephemeris was computed from the elements of the foregoing article, p. 101. A comparison with the latest known observation, by Prof. Frisby, Nov. 16, gives the corrections, $\Delta\alpha = +0^{s}.4$, $\Delta\delta = +0'.3$.

FILAR-MICROMETER OBSERVATIONS OF COMET *d* 1889 (*BROOKS*),

MADE WITH THE 9.5-INCH EQUATORIAL OF THE JOHNS HOPKINS UNIVERSITY,

By C. A. Borst.

[Communicated by Prof. Newcomb.]

Greenwich M.T.	*	No. Comp.	☄ — *		☄'s apparent		log pΔ	
			Δα	Δδ	α	δ	for α	for δ
d h m s			m s	′ ″	h m s	° ′ ″		
Oct. 15 16 28 40.4	*a*	5 , 3	—0 41.27	+0 15.5	23 41 20.33	—4 8 30.6	9.184	0.946
16 15 45 39.4	*a*	5 , 3	—0 55.30	+1 55.9	23 41 6.30	—4 3 55.3	8.619	0.947
17 14 7 56.2	*b*	15 , 3	+0 25.66	+2 18.9	23 40 53.98	—3 59 7.7	*n*8.902	0.946
19 13 53 59.3	*c*	5 , 3	+1 41.74	—1 55.9	23 40 34.65	—3 49 8.7	*n*9.046	0.945
21 14 39 25.7	*d*	6 , 3	—0 27.45	—1 31.0	23 40 19.61	—3 38 10.3	*n*8.160	0.944

Mean Places for 1889.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place.	Authority
	h m s	s	° ′ ″	″	
a	23 41 59.17	+2.43	—4 9 6.6	+15.5	Lalande 46612
b	23 40 25.90	+2.42	—4 1 42.2	+15.6	Gould 32111
c	23 38 50.51	+2.40	—3 47 28.2	+15.4	Grant 6281
d	23 40 44.62	+2.44	—3 36 54.6	+15.3	Comparisons with *c*

The observations were quite difficult, owing to the illumination of the air by electric lights in the vicinity.

COMET *f* 1889.

A dispatch from Rochester, received Nov. 18, announces the discovery of a new comet by Swift. The position given is probably in time of the meridian of 5^{h} from Greenwich.

1889 Nov. 17, $6^{h}\,45^{m}$, $\alpha = 22^{h}\,42^{m}\,25^{s}$, $\delta = +11°\,51'$. Daily motion, 2^{m} in α and $15'$ northward. Faint, no tail.

An observation of this comet has been received from the Lick Observatory, where it was observed by Mr. Barnard,

1889 Nov. 20.6704 Greenw. M.T. $\alpha = 22^{h}\,49^{m}\,19^{s}.0$ $\delta = +12°\,45'\,52''$.

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Comet *f* 1889.

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METHOD OF COMPUTING AN ORBIT FROM THREE COMPLETE OBSERVATIONS.

By Rev. GEO. M. SEARLE.

This method is intended specially for the orbits of comets; though it is applicable in all cases.

Various formulas employed in it have been given in previous numbers of the *Astronomical Journal;* but as it has recently seemed expedient to put it in quite a different shape, especially by taking a different dimension of the orbit for the coincidence (the one now used being substantially the same as that employed by Gauss), and to calculate the quantity $rr'' \cos 2f'$ instead of the chord, thereby much simplifying the formulas of Olbers's method, it seems necessary to state the course to be pursued entirely anew.

It will be seen, as we proceed, that where the angles traversed by the radius-vector of the body are not too large, the equation for its distance assumes the following very simple form, similar to that of the equation of Gauss;

$$\sin(Y - Y_0) = m \sin^4 Y \text{(or in some cases, } m \sin^4 Y \cos^{1/2} 2Y)$$

in which Y is a fictitious angle, not the same as the z of Gauss, from which however the distance can be easily computed; and Y_0 and m are constants obtained approximately without much trouble from the observations, and easily corrected from one hypothesis to another.

The fundamental unknown quantity taken is the ratio of the triangles in the orbit. This ratio being known, it is clear that for any assumed value of ρ the first curtate distance, we have the third, ρ'', and that thus the plane of the orbit is determined. It follows from this, that the points of intersection of the three lines of observation with this plane are known; and as three points, with the focus, completely determine a conic section, that any dimension of this conic section is ascertainable from these points.

But the same dimension can also be obtained from the two extreme points and the intervening time.

Now the value of ρ may be so taken that the two values of the dimension chosen, determined in these two different ways, shall agree.

Various dimensions might be chosen for this purpose; we shall select the ratio $\eta' = \frac{\text{sector}}{\text{triangle}}$ between the extreme points. This is, as is well known, readily determined from the two radii, the intervening angle and the time; it is also determined, by means of the parameter, from the three points.

And it is clear that two conic sections having two radii and the included angle, together with this ratio η', the same, must coincide entirely; for if the ratio η' is the same, the sectors must be equal in area in the two; but for this it is manifest that the curves must cross at least one point between the two extreme ones. But if so, they have three points in common, and must entirely coincide.

Now to determine η' from the three points.

We have, using the notation of Gauss,

$$\frac{1}{p} = \frac{n + n'' - n'}{4rr'r'' \sin f \sin f' \sin f''} = \frac{1 + \frac{n''}{n} - \frac{r \sin 2f'}{r' \sin 2f}}{2r \sec f \sin f' \sin f''}$$

Now r', as determined by the intersection, is given by the formula

$$\frac{r \sin 2f'}{r' \sin 2f} = 1 + N_0 + Pr^{-1}l + Q\rho\,,$$

in which N_0 is a constant determined by the places of the earth, P and Q constants determined by the places of the earth and the observations, ρ the first curtate distance, $r = \frac{n}{n''}$ or the assumed ratio of the triangles, and l a quantity dependent on r and constants. We have then, denoting $r^{-1} - Pr^{-1}l - N_0$ by N_1

$$\frac{1}{p} = \frac{N_1 - Q\rho}{2r \sec f \sin f' \sin f''}$$

The formula above for $\frac{r \sin 2f'}{r' \sin 2f}$ is substantially the same as [9] Art. 141. *Theoria Motus.*

Now $\eta' n' = k(t'' - t)\sqrt{p} = \theta' \sqrt{p}$ in the notation of Gauss. We have then

$$\frac{1}{\eta'^2} = \frac{(rr'')^2 \sin^2 2f'}{\theta'^2} \cdot \frac{N_1 - Q\rho}{2r \sec f \sin f' \sin f''}$$

$$= \frac{r''^2 r \cos f \cos f'' \sin 2f'}{\theta'^2 \sin f'} (N_1 - Q\rho)$$

We have now all that we need for solving each hypothesis for r. Assuming ρ we can obtain from it r, r'', f, f', f''. these give the value of $\frac{1}{\eta'^2}$ as determined by the three points, while Gauss's process gives the same quantity as determined for r, r'', f' and the time; determining then, by trial, for what value of our assumed quantity the two shall coincide, the two conic sections will for this value entirely coincide, and the only thing now necessary, to verify or correct the assumed value of r, will be to see whether the middle radius-vector as determined by the time falls on that determined by the middle line of observation.

It is easy to compute accurately the ratio of the sectors, as determined by the intersections. For we have

$$\eta - 1 = \frac{2}{3p}\,\frac{\sqrt{r'r''}\,\sin f\tan f}{1-\frac{6}{5}(x-\xi)}$$

and similar ones for $\eta'-1$ and $\eta''-1$.

We have then

$$\frac{\eta'-1}{\eta-1} = \sqrt{\frac{r\sin 2f'}{r'\sin 2f}}\sqrt{\frac{\tan^3 f'}{\tan^3 f}}\;\frac{1-\frac{6}{5}(x-\xi)}{1-\frac{6}{5}(x'-\xi')}$$

(For the hyperbola, substitute $z+\zeta$ for $x-\xi$.)

This gives, denoting $1+N_0+Pr^{-1}l = 1+r^{-1}-N_1$ by N_2,

$$\frac{\eta'-1}{\eta-1} = \frac{\sqrt{(N_2+Q\rho)\tan^3 f}}{1-\frac{6}{5}(x'-\xi')}\cdot\frac{1-\frac{6}{5}(x-\xi)}{\sqrt{\tan^3 f}}$$

Similarly we shall obtain

$$\frac{\eta'-1}{\eta''-1} = \sqrt{r}\;\frac{\sqrt{(N_2+Q\rho)\tan^3 f'}}{1-\frac{6}{5}(x'-\xi')}\cdot\frac{1-\frac{6}{5}(x''-\xi'')}{\sqrt{\tan^3 f''}}$$

or, since

$$(\eta'-1)[1-\tfrac{6}{5}(x'-\xi')] = \tfrac{4}{3}\,\frac{m^2}{\eta'^2}\quad(\textit{Theoria Motus}, \text{Art. } 91,)$$

we have

$$\eta-1 = \frac{m^2}{\eta'^2}\cdot\frac{4}{3\sqrt{(N_2+Q\rho)\tan^3 f'}}\cdot\frac{\sqrt{\tan^3 f}}{1-\frac{6}{5}(x-\xi)},$$

$$\eta''-1 = \sqrt{r^{-1}}\,\frac{m^2}{\eta'^2}\cdot\frac{4}{3\sqrt{(N_2+Q\rho)\tan^3 f'}}\cdot\frac{\sqrt{\tan^3 f''}}{1-\frac{6}{5}(x''-\xi'')}$$

These formulas for obtaining η and η'' are entirely dependent on the angles f, f', f'' and the radii r, r', r'', if we determine x, x'' or z, z'' by the formulas

$$\frac{\sin^2 g}{\sin^2 g'}\left(\text{or }\frac{\tan^2 2n}{\tan^2 2n'}\right) = \frac{r'}{r}\,\frac{\sin^2 f}{\sin^2 f'} = \frac{\tan f}{(N_2+Q\rho)\tan f'}$$

$$\frac{\sin^2 g}{\sin^2 g''}\left(\text{or }\frac{\tan^2 2n''}{\tan^2 2n'}\right) = \frac{r'}{r''}\,\frac{\sin^2 f''}{\sin^2 f'} = \frac{r^{-1}\tan f''}{(N_2+Q\rho)\tan f'}$$

For $\frac{\sin^2 g}{\sin^2 g'}$, we may write with perfect accuracy $\frac{x(1-x)}{x'(1-x')}$ or for $\frac{\tan^2 2n}{\tan^2 2n'}$, $\frac{z(1+z)}{z'(1+z')}$; and usually we may safely neglect $\frac{1-x}{1-x'}$ or $\frac{1+z}{1+z'}$. We have then

$$x = \frac{(x'-x'^2)}{(N_2+Q\rho)\tan f'}\quad\tan f + x^2$$

$$x'' = \frac{(x'-x'^2)}{(N_2+Q\rho)\tan f'}\cdot\frac{\tan f''}{r} + x''^2$$

$$z = \frac{(z'+z'^2)}{(N_2+Q\rho)\tan f'}\cdot\tan f - z^2$$

$$z'' = \frac{(z'+z'^2)}{(N_2+Q\rho)\tan f'}\cdot\frac{\tan f''}{r} - z''^2$$

in which as a rule, x^2, x'^2, x''^2, z^2, z'^2, z''^2 may be neglected.

It is not, however, necessary to compute both $\eta-1$ and $\eta''-1$, unless indeed we are aiming at extreme accuracy. For we have, as is plain,

$$\begin{aligned}\eta' r r''\sin 2f' &= \eta r' r''\sin 2f + \eta'' r r'\sin 2f'' \\ &= \eta r' r''\sin 2f\left(1+\frac{\eta''}{\eta}r^{-1}\right)\end{aligned}$$

$$\text{or}\quad\frac{\eta' r r''\sin 2f'}{\eta r' r''\sin 2f} = \frac{\eta'}{\eta}(N_2+Q\rho) = 1+\frac{\eta''}{\eta}r^{-1}$$

From this we have $N_2+Q\rho = \frac{\eta}{\eta'}+\frac{\eta''}{\eta'}r^{-1}$

$$\frac{\eta''}{\eta} = \left[\frac{\eta'}{\eta}(N_2+Q\rho)-1\right]r.$$

We can then merely compute η and obtain η'' by this formula; we also have, if preferred,

$\frac{\eta}{\eta''} = \frac{\eta'}{\eta''}(N_2+Q\rho)-r^{-1}$ by which, having computed η'' by the formulas for x'' and $(\eta''-1)$, we have η by this.

The above expressions for $\eta-1$ and $\eta''-1$ are available for the correction of r; but if we should attempt to determine η^2 and η''^2 directly on the principle that

$$\frac{4m^2}{3\eta^2} = (\eta-1)\,(1-\tfrac{6}{5}(x-\xi),)$$

we should simply beg the question that the sectors were proportional to θ and θ'', or that the middle radii in the two orbits coincided; and should find, as will easily be seen, that $\frac{\eta''}{\eta}:\frac{(t''-t')}{(t'-t)}$ simply gave us our original value of r.

By computing η and η'' in the above manner, however, we obtain their real values for the points determined by the intersections, and shall obtain a real improvement in r by the above formula; with this, if we please, f and f'' may be recomputed, and from them η and η'', and r still further refined, before proceeding to the next hypothesis. But this, as a rule, is hardly worth while.

It remains to give a method for the trial to make the two values of $\frac{1}{\eta'^2}$ coincide.

This equation for $\frac{1}{\eta'^2}$ given above might serve for the trial in its present form, with ρ as the quantity to be assumed. Evidently, from r and ρ all the variable quantities in it can be computed and the resulting value of $\frac{1}{\eta'^2}$ compared with that resulting from the time with r, r'' and f'.

But this can probably be better done, as the time-value of $\frac{1}{\eta'^2}$ is more generally accurate, and varies slower than the other, by making

$$N_1 - Q\rho = \frac{\theta'^2\sin f''\sec f\sec f'}{r''^2 r\sin 2f'}\cdot\frac{1}{\eta'^2}$$

Assuming ρ, we may compute the first factor of the second member, then multiply by the time-value of $\frac{1}{\eta'^2}$, and thus obtain an improved value of ρ. This having been performed twice, a sufficiently accurate value is got by an interpolation formula.

But we can put this equation in a more convenient shape. We make

$$\frac{\sin f''}{\sin 2f'} = \frac{\sin 2f''}{2\cos f''\sin 2f'} = \frac{r''}{2r'}\sec f''\,\frac{\theta''}{\iota''}\cdot\frac{\iota'}{\theta'}$$

This gives

$$N_1 - Q\rho = \frac{\theta'\theta''}{2rr'r''}\cdot\frac{\sec f\sec f'\sec f''}{\iota'\iota''}$$

$$= \frac{\theta'\theta''}{2(rr'')^{3/2}}\cdot\frac{\sqrt{rr''}}{r'}\cdot\frac{\sec f\sec f'\sec f''}{\iota'\iota''}$$

This may be written

$$N_1 - Q\rho = X\,\frac{\theta'\theta''}{2(rr'')^{3/2}}$$

in which X is a quantity near unity for moderate values of f', and varying slowly for changes in ρ.

We may, however, give this equation a form which is in some cases still more convenient, namely

$$N_1 - Q\rho = X\cos^{3/2}2f'\,\frac{\theta'\theta''}{2[rr''\cos 2f']^{3/2}}$$

$$\text{or}\quad X'\,\frac{\theta'\theta''}{2[rr''\cos 2f']^{3/2}}$$

The advantage of this is that $rr''\cos 2f'$ is easily expressed in terms of ρ. We have, denoting the rectangular coordinates of the body by the usual symbols,

$$rr''\cos 2f' = xx'' + yy'' + zz''$$

and making $\cos(\lambda''-\lambda) + \tan\beta\tan\beta'' = e$

and $\rho'' = M\rho + l$, in which M is a constant multiple of the ratio of the triangles, and l a simple function of r and known quantities,

$$\frac{rr''\cos 2f'}{eM} = \rho^2 - \left[\frac{R\cos(\lambda''-L)}{e} + \frac{R''\cos(\lambda-L'')}{e}\cdot\frac{1}{M} - \frac{l}{M}\right]\rho$$
$$+ \frac{RR''\cos(L''-L)}{eM} - \frac{R\cos(\lambda''-L)}{e}\cdot\frac{l}{M}$$

Making now $\frac{\varepsilon}{2} + \frac{\varepsilon''-l}{2M} = \rho_0$ and $\frac{\varepsilon'}{M} - \frac{\varepsilon l}{M} - \rho_0^2 = n$,

we have $\frac{rr''\cos 2f'}{eM} = (\rho-\rho_0)^2 + n$. The values of ε, ε', ε'' are readily perceived.

Denoting now $\rho - \rho_0$ by y, the equation for trial becomes, if we put $\frac{N_1}{Q} - \rho_0 = y_0$

$$y = y_0 - \frac{X'\theta'\theta''}{2Qe^{3/2}M^{3/2}}(y^2+n)^{-3/2}$$

In this, $\frac{\theta'\theta''}{2Q}$ is constant while the observations and the times remain unchanged. M is of course constant for each hypothesis:

$$X' = \frac{\sqrt{rr''}}{r'}\cdot\frac{\sec f\sec f'\sec f''\cos^{3/2}2f'}{\iota'\iota''}$$

does not vary much if f' is not too large, and may be taken from a previous hypothesis or a previous orbit; if there is no previous hypothesis or orbit, it may be taken equal to unity to start with.

We have then, dividing the equation for y by $\sqrt{n}$, and denoting

$$\frac{X'\theta'\theta''}{2Qe^{3/2}M^{3/2}n^2}\ \text{by}\ m:$$

$$\frac{y}{\sqrt{n}} = \frac{y_0}{\sqrt{n}} - m\left(\frac{y^2}{n}+1\right)^{-3/2}$$

If n is negative, we divide by $\sqrt{-n}$, and have

$$\frac{y}{\sqrt{-n}} = \frac{y_0}{\sqrt{-n}} - m\left(\frac{y^2}{-n}-1\right)^{-3/2}$$

We now make $\frac{\sqrt{\pm n}}{y} = \tan Y$, $\frac{\sqrt{\pm n}}{y_0} = \tan Y_0$; these equations then become, for n positive, if we make

$$m_0\sin Y_0 = m$$
$$\sin(Y-Y_0) = m\sin^4 Y$$

which has the same form as the equation of GAUSS; and for n negative,

$$\sin(Y-Y_0) = m\sin^4 Y\cos^{-3/2}2Y.$$

When Q is zero, or very small, we may put

$$\tan Y_0 = \frac{\sqrt{\pm nQ}}{N_1-Q\rho_0}\qquad m = \frac{X'\theta'\theta''}{2e^{3/2}M^{3/2}n^2}\cdot\frac{\cos Y_0}{N_1-Q\rho_0}$$

in which n is always positive.

Several special cases arise.

1. When n is very near zero, the equation is perhaps better solved in its unchanged form.

$$y = y_0 - \frac{\theta'\theta''}{2Qe^{3/2}}\cdot\frac{X'}{M^{3/2}}(y^2+n)^{-3/2}\quad\text{(to be multiplied by } Q$$

if this is also very small).

2. When $y^2 + n$ is very small, $\cos 2f'$ must also be very small, unless the latitudes are high, or M has an unusually large value, owing probably to great proximity of the object; if $\cos 2f'$ is small, or in general if $2f'$ has a value $>60°$, it is probable that the first equation (with X) should be preferred.

3. When $y^2 + n$ is negative, it is certain that either eM or $\cos 2f'$ is negative; for the whole term, being equal to $\frac{X\theta'\theta''}{2Q(rr'')^{3/2}}$ is certainly real; if $\cos 2f'$ is negative, we had better adopt the other equation; but if eM is negative, its sign as well as that of $y^2 + n$, may be considered positive, as far as the solution of this equation is concerned.

In most cases, however, in which the use of this method is contemplated, both eM and $\cos 2f'$ will be not very far from $+1$; and indeed n will be generally positive; for ε usually is not large; and making e and $M = 1$ and $l = 0$,

$$\rho_0 = \frac{R\cos(\lambda''-L) + R''\cos(\lambda-L'')}{2}$$

the maximum value of which is

$\frac{R+R''}{2}$ which will not much exceed $\sqrt{\varepsilon'} = \sqrt{RR''\cos(L''-L)}$

When $2f'$ has a value $>60°$, it will generally be well, as has been said, to fall back on the previous equation, in which, instead of X', X is used. For this we have

$$\rho = \frac{N_1}{Q} - \frac{\theta'\theta''}{2Q} X(rr'')^{-\frac{1}{2}}$$

and by this we can make the trial; though not quite so conveniently, for we must here compute r and r'' separately.

The formulas for these are however quite simple. For r, we have

$$r^2 = \rho^2 \sec^2\beta + R^2 - 2R\rho\cos(\lambda - L)$$

or

$$r^2\cos^2\beta = [\rho - R\cos(\lambda - L)\cos^2\beta]^2 + R^2\cos^2\beta\,[1 - \cos^2(\lambda - L)\cos^2\beta]$$

If in this we make $\cos(\lambda - L)\cos\beta = \cos\psi$, this becomes, if we also put $B = R\sin\psi\cos\beta$ and $C = -R\cos\psi\cos\beta$,

$$r^2\cos^2\beta = (\rho + C)^2 + B^2$$

For r''^2, we have

$$r''^2 = (M\rho + l)^2\sec^2\beta + R''^2 - 2R''(M\rho + l)\cos(\lambda'' - L'')$$

which reduces to

$$\frac{r''^2\cos^2\beta''}{M^2} = (\rho + C_0'')^2 + \frac{B''^2}{M^2}$$

if we make as before, $\cos(\lambda'' - L'')\cos\beta'' = \cos\psi''$,

$$B'' = R''\sin\psi''\cos\beta'' \qquad C'' = -R''\cos\psi''\cos\beta''$$

and

$$C_0'' = \frac{C'' + l}{M}$$

Having solved, then, either of these equations by trial, we compute $\cos 2f'$ by the formula

$$\cos 2f' = \frac{eM(y^2 + n)}{rr''} = \frac{neM}{rr''}\left(\frac{y^2}{n} + 1\right)$$

in which $\frac{y^2}{n} + 1 = \operatorname{cosec}^2 Y$ for n positive,

or $= -\cos 2Y \operatorname{cosec}^2 Y$ for n negative.

From this we readily obtain f and f'' by means of r, r, and r''; then η', η and η'' by the processes given above.

It may be objected that f' is not attainable with great accuracy by the equation for $\cos 2f'$; but, after all, it is only needed for the computation of η and η'', and the accuracy, if obtained, would be nearly useless.

The formulas used in this method would no doubt in some respects be simplified if we should take M, the ratio of the curtate distances, as our unknown quantity, instead of r the ratio of the triangles; but as we need the latter quantity in the subsequent work, and should have to continually recompute it by the formula

$$r = \frac{aM\rho - N}{b\rho - N''}$$

we should perhaps rather lose than gain; and moreover, as we should be obliged to get M, for a new hypothesis, by the formula

$$M = r\frac{b}{a} + \frac{N - rN''}{a\rho}$$

in which ρ would have to be taken from the last hypothesis, it is probable that the hypotheses for M would not be so convergent as for r, since there would be the additional uncertainty as to the value of ρ.

It will be noticed that our unknown quantities r and X (or X') are nearly the same as those of Gauss.

For the computation of a first parabolic orbit, it will not be advisable to use this method, since more or less departure from the parabolic form would very probably be indicated (owing to the want of perfect accuracy in the observations), which, however, would not be reliable. In this case we must assume the parabolic form and the parabolic time-equation, which can be put, when the intervals of time are short, into a little more simple a shape.

We have for this equation, making $\sqrt{rr''}\cos f' = r_0$,

$$\frac{3\theta'}{2} = (r + r'' + r_0)\left(\frac{r + r''}{2} - r_0\right)^{1/2}$$

Or denoting $\frac{r + r''}{2r_0} - 1$ by x', and the chord by κ, we have, since $\kappa^2 = (r + r'')^2 - 4r_0^2$,

$$\frac{9\theta'^2}{4} = \frac{(r + r'' + r_0)^2}{2(r + r'' + 2r_0)} \cdot \kappa^2 = \frac{(3 + 2x')^2}{4x' + 8} \cdot \kappa^2 r_0$$

or

$$2\theta'^2 = [1 + \tfrac{5}{6}x' + \tfrac{1}{36}x'^2 - \tfrac{1}{72}x'^3 \,\&\text{c.}]\,\kappa^2 r_0$$

We also have, dividing the square of the first equation by r_0^3, $\frac{9\theta'^2}{4r_0^3} = (3 + 2x')^2 x'$; and now, denoting $\frac{\theta'^2}{4r_0^3}$ by x

$$x = x' + \tfrac{4}{3}x'^2 + \tfrac{4}{9}x'^3$$

By means of this we can turn the series containing x' into one in terms of x; which gives $1 + \frac{5}{6}x - \frac{13}{12}x^2 + \frac{541}{216}x^3$ &c.

Denoting this by X, we have $2\theta'^2 = X\kappa^2 r_0$ in which X is a function of x, and easily tabulated for small values of x.

For the time-equation, now, instead of calculating r, r'', and κ, we shall only have to compute r_0 and κ from the observations.

Now r_0 cannot be directly computed, but $rr''\cos 2f'$ can; and we have, with all necessary approximation for small values of f',

$$\tan 2f' = \frac{\kappa}{\sqrt{rr''\cos 2f'}} \qquad r_0 = \sqrt{rr''\cos 2f'} \cdot \sec f'$$

The value of $\sec f'$, and still more of X, when obtained for a value of ρ anywhere near the truth, will suffice for the trial.

For a first parabolic orbit, we shall assume $\rho'' = M\rho$, in which M may be $= \frac{t'' - t'}{t' - t} \cdot \frac{b}{a}$ or $\frac{N}{N''} \cdot \frac{b}{a}$, as preferred

We have then also to compute

$$c = \sec^2\beta + M^2\sec^2\beta''$$

$$e = \cos(\lambda'' - \lambda) + \tan\beta\tan\beta''$$

$$h_0 = R\cos(\lambda - L) + MR''\cos(\lambda'' - L'')$$

$$h = R''\cos(\lambda - L'') + MR\cos(\lambda'' - L)$$

$$g^2 = (R'' - R)^2 + 4RR''\sin^2\tfrac{1}{2}(L'' - L)$$

$$\rho_0 = \frac{h}{2eM}$$

$$n = \frac{RR''\cos(L'' - L)}{eM} - \rho_0^2$$

$$i = c - 2eM$$

$$d = \frac{2(h - h_0)}{i}$$

Then for the trial,

$$\kappa^2 = g^2 + i\rho(\rho + d)$$

and denoting $\sqrt{rr''\cos 2f'}$ by r_1,

$$r_1^2 = eM\left[(\rho-\rho_0)^2+n\right]$$

For this, we may make

$$y = \rho - \rho_0 \quad ; \quad \tan Y = \frac{\sqrt{n}}{y}$$

$$r_1 = \sqrt{neM}\,\operatorname{cosec} Y.$$

$$\tan 2f'' = \frac{\kappa}{r_1} \quad ; \quad r_0 = r_1 \sec f' : \text{ from this } x \text{ and } X.$$

Then $X\kappa^2 r_0 = 2\theta'^2$.

(For the first trials, we may take simply $\kappa^2 r_1 = 2\theta'^2$. This being approximately solved, sec f'' and X may be introduced without need of any subsequent change.

This equation being satisfied, we compute the elements down to u and u'' by the formulas given below; then, making $\sqrt[4]{\frac{r}{r''}} = \tan(45-\omega)$, we have

$$\tan \tfrac{1}{2} F' = \sin 2\omega \cot \tfrac{1}{2} f''$$

and from this e and v'', $\pi - \Omega$, q, and T.

The following table will generally suffice for X.

x	log X	x	log X
0.001	0.000361	0.006	0.002150
.002	.000721	.007	.002504
.003	.001080	.008	.002857
.004	.001438	.009	.003209
0.005	0.001795	0.010	0.003559

We proceed now to give the formulas for practical computation for the general case. The longitudes and latitudes are denoted by $\lambda, \lambda', \lambda'', \beta, \beta', \beta''$; the corresponding times by t, t', t''; the longitudes of the sun and radii-vectores of the earth by L, L', L'', R, R', R''.

It will be well in preparing these data to employ the third method of Gauss, correcting the places for stellar aberration: since if there be a departure from a parabolic form in the orbit the distance may require considerable correction, so that if we employ either of the other methods, we may have to recompute the constants which lie at the basis of the work.

Formulas for Practical Computation.

Quantities to be computed once for all.

$$N = R'R'' \sin(L''-L')$$

$$N'' = RR' \sin(L'-L)$$

$$N_0 = \frac{RR''\sin(L''-L)}{N} - 1$$

$$m' = \sin(\lambda'-L')\cot\beta'$$

$$a = R'[\sin(\lambda''-L') - m'\tan\beta'']$$

$$b = R'[m'\tan\beta - \sin(\lambda-L')]$$

$$P = \frac{R''}{N}\left[\sin(\lambda''-L'') - \sin(\lambda'-L'')\tan\beta'\cot\beta'\right]$$

$$Q = \frac{1}{a}\left[\sin(\lambda''-\lambda')\frac{\tan\beta}{\tan\beta'} + \sin(\lambda'-\lambda)\frac{\tan\beta''}{\tan\beta'} - \sin(\lambda''-\lambda)\right]$$

$$e = \cos(\lambda''-\lambda) + \tan\beta\tan\beta''$$

$$\varepsilon = \frac{R\cos(\lambda''-L)}{e}$$

$$\varepsilon' = \frac{RR''\cos(L''-L)}{e}$$

$$\varepsilon'' = \frac{R''\cos(\lambda-L'')}{e}$$

$$\cos\psi = \cos\beta\cos(\lambda-L)$$

$$\cos\psi'' = \cos\beta''\cos(\lambda''-L'')$$

$$\left.\begin{aligned} B &= R\sin\psi\cos\beta \\ B'' &= R''\sin\psi''\cos\beta'' \end{aligned}\right\} \text{always positive}$$

$$C = -R\cos\psi\cos\beta$$

$$C'' = -R''\cos\psi''\cos\beta''$$

For each hypothesis assume r, and compute

$$M = \mathrm{r}\frac{b}{a} \qquad l = \frac{N - \mathrm{r}N''}{a}$$

If we have no previous approximation for r, we may make it $= \frac{N}{N''}$, so that $l = 0$

$$C''_0 = \frac{C''+l}{M} \qquad N_1 = \mathrm{r}^{-1} - (P\mathrm{r}^{-1}l + N_0)$$

$$2\rho_0 = \varepsilon + \frac{\varepsilon''-l}{M} \qquad N_2 = 1 + (P\mathrm{r}^{-1}l + N_0)$$

$$n = \frac{\varepsilon' - \varepsilon l - M\rho_0^2}{M} \qquad y_0 = \frac{N_1}{Q}\rho_0$$

$$X' = \frac{\sqrt{rr''}}{r'}\,\frac{\sec f\sec f'\sec f''\cos^{3/2}2f'}{t_1't_1''} \qquad m_0 = \frac{\theta'\theta''X}{2(Qr^{-4}-Mr^{-4}n)}$$

The quantities X', y_0 and m_0 are only computed when $2f'$ is small enough to proceed by that special process. Otherwise, compute

$$X = \frac{\sqrt{rr''}}{r'}\,\frac{\sec f\sec f'\sec f''}{t_1't_1''}, \quad \frac{N_1}{Q}, \text{ and } \frac{\theta'\theta''X}{2Q}$$

If there be a previous hypothesis, it furnishes the values for X or X'. For the first hypothesis, if there be a previous orbit, make

$$X = \frac{2(rr'')^{3/2}}{\theta'\theta''}\cdot\frac{2r}{p}\sec f\sin f'\sin f''$$

and X' the same value multiplied by $\cos^{3/2}2f'$. If there be no previous orbit or hypothesis, make X and $X' = 1$.

Making now, for the X' method,

$$\tan Y_0 = \frac{\sqrt{\pm n}}{y_0}, \quad m = m_0\sin Y_0,$$

our equation for Y is, for n positive,

$$\sin(Y - Y_0) = m\sin^4 Y$$

For n negative, we have

$$\sin(Y - Y_0) = m\sin^4 Y\cos^{-2}2Y$$

We have for the first value of Y in the trial, for a new hypothesis, the value of Y obtained in the last hypothesis. After finding

$$y = \frac{\sqrt{\pm n}}{\tan Y}$$

we have $\rho = \rho_0 + y$, $rr'' \cos 2f' = neM \operatorname{cosec}^2 Y$
or $-neM \cos 2Y \operatorname{cosec}^2 Y$,

and r and r'' by the formulas

$$\tan\zeta = \frac{\rho + C}{B} \qquad r = B \sec\beta \sec\zeta$$

$$\tan\zeta'' = \frac{M}{B''}(\rho + C_0'') \qquad r'' = B'' \sec\beta'' \sec\zeta''$$

If $2f'$ is too large for us to pursue this process with sufficient approximation, we put, as remarked above,

$$N = \frac{\sqrt{rr''}}{r'} \frac{\sec f \sec f' \sec f''}{\eta' \eta''}$$

, the quantities r, r', r'', &c., to be taken from the last hypothesis.

We have for a first value of ρ in the trial, if there be a previous orbit.

$$\rho = \frac{N_1}{Q} - \frac{2r}{pQ} \sec f \sin f' \sin f''$$

The equation for the trial is

$$p = \frac{N_1}{Q} - \frac{\theta'\theta''}{2Q} N (rr'')^{-3/2}$$

in which rr'' must be computed for the assumed value of p by the formulas for $\tan\zeta$, $\tan\zeta''$ above, which makes the trial somewhat more laborious.

For the first value of ρ in a new hypothesis assume it as determined in the last.

From ρ we obtain

$$y = \rho - \rho_0 \text{ and } rr'' \cos 2f' = eM(y^2 + n)$$

Having now obtained r, r'' and $2f'$ by one of these trial equations, we proceed to compute η', and from it η and η''.

First, for η'. Making $\sqrt{rr''} \cos f' = r_0$ we have

$$\tfrac{5}{6} + l = \tfrac{1}{3} + \frac{r + r''}{4r_0} \quad ; \quad m^2 = \frac{\theta'^2}{8r_0^3} \quad ; \quad h = \frac{m^2}{\frac{5}{6} + l}$$

and η'^2 from h by Gauss's table. For the moderate values of f' with which we expect to deal, ξ or ζ may practically be neglected.

$x' = \dfrac{m^2}{\eta'^2} - l$, positive for the ellipse, negative for the hyperbola.

For f and f'';

$$\tan\vartheta = \frac{r}{r''} \qquad \tan(f - f'') = \tan(\vartheta - 45°) \tan f'$$

For x and x''. Making $\rho_1 = N_2 + Q\rho$

$$x = \frac{x' - x'^2}{\rho_1 \tan f'} . \tan f + x^2$$

$$x'' = \frac{x' - x'^2}{\rho_1 \tan f'} . \frac{\tan f''}{r} + x''^2$$

usually, x^2, x'^2, x''^2 may be neglected.

Then
$$\eta - 1 = \frac{m^2}{\eta'^2} \cdot \frac{4}{3\sqrt{\rho_1 \tan^3 f'}} \cdot \frac{\sqrt{\tan^3 f}}{1 - \frac{6}{5}x}$$

$$\eta'' - 1 = \frac{m^2}{\eta'^2} \cdot \frac{4}{3\sqrt{\rho_1 \tan^3 f'}} \cdot \frac{\sqrt{r^{-1} \tan^3 f''}}{1 - \frac{6}{5}x''}$$

Check; by which either η or η'' may be computed from the other if preferred.

$$\frac{\eta''}{\eta} = \left(\frac{\eta'}{\eta}\rho_1 - 1\right) r \qquad \text{or} \qquad \frac{\eta}{\eta''} = \frac{\eta'}{\eta''}\rho_1 - r^{-1}$$

From these we obtain $\dfrac{\eta''(t''-t')}{\eta\ (t'-t)} = r$ for another hypothesis.

$$\frac{1}{r'} \text{(to be used for the new hypothesis)} = \frac{\rho_1 \sin 2f}{r \sin 2f'}$$

The formulas for the distances $\Delta, \Delta', \Delta''$, if desired at the end of any hypothesis to obtain corrections to the times, are, for Δ and Δ'',

$$\Delta = \rho \sec\beta \qquad \Delta'' = (M\rho + l) \sec\beta''$$

for Δ', $\cos\psi' = \cos\beta' \cos(\lambda' - L')$; $\sin z = \dfrac{R' \sin\psi'}{r'}$

$$\Delta' = R' \cos\psi' \pm r \cos z.$$

There can rarely be any ambiguity in Δ', since it must usually be near Δ and Δ''.

If, however, we wish to remove all ambiguity, we may compute from the plane itself, by the formulas

$$P' = Q + \frac{R''}{N}[\sin(\lambda'' - L'') \tan\beta \cot\beta'' - \sin(\lambda - L'')]$$

(computed once for all)

$$\Delta' = \frac{\tan\beta''}{P\rho_1 \sin\beta'}[P'\rho + Pr^{-1} l]$$

At the end of any hypothesis in which r and N, or N' show no material improvement, we proceed to compute the elements.

For this we first obtain the elements of position of the plane. We have the values of ρ and of $\rho'' = M\rho + l$.

Then
$$r \cos b \cos(l - L) = \rho \cos(\lambda - L) - R$$
$$r \cos b \sin(l - L) = \rho \sin(\lambda - L)$$
$$r \sin b = \rho \tan\beta$$

and similarly for r'', l'', b''. The values of r and r'' should be the same as determined before.

$$\tan[\tfrac{1}{2}(l'' + l) - \Omega] = \frac{\sin(b'' + b)}{\sin(b'' - b)} \tan\tfrac{1}{2}(l'' - l)$$

$$\tan i = \frac{\tan b}{\sin(l - \Omega)} = \frac{\tan b''}{\sin(l'' - \Omega)}$$

$$\tan u = \tan(l - \Omega) \sec i \qquad \tan u'' = \tan(l'' - \Omega) \sec i$$

$$2f' = u'' - u.$$

This is a more accurate determination of $2f'$ than that previously made, and we will use it to obtain the elements of the dimensions of the orbit.

Make, for the ellipse, $\sin^2 \tfrac{1}{2} g' = x'$

Then
$$\tan(45 - \omega) = \sqrt[4]{\frac{r}{r''}}$$

$$P \sin\tfrac{1}{2}(F' - G') = \tan 2\omega \cos\tfrac{1}{2}(f' + g')$$
$$P \cos\tfrac{1}{2}(F' - G') = \sec 2\omega \sin\tfrac{1}{2}(f' + g')$$
$$Q \sin\tfrac{1}{2}(F' + G') = \tan 2\omega \cos\tfrac{1}{2}(f' - g')$$
$$Q \cos\tfrac{1}{2}(F' + G') = \sec 2\omega \sin\tfrac{1}{2}(f' - g')$$

P and Q have the sign of $\sin g'$: practically always positive.

$$P = R\cos\tfrac{1}{2}\varphi \qquad Q = R\sin\tfrac{1}{2}\varphi$$

$$\text{Check:}\quad R^2 = 2\,\frac{m^2}{\eta'^2}\cos f'$$

$$a = \frac{R^2\sqrt{rr''}}{\sin^2 g'} \qquad p = \frac{\sqrt{rr'}\,\sin^2 f'}{R^2}$$

When x' is negative, it can be made $= -z'$; and the formulas for this rare case may be found in the *Theoria Motus*.

For v, v'', E and E''; $v = F' - f'$, $v'' = F' + f'$; $E = G' - g'$, $E'' = G' + g'$.

For ellipses decidedly differing from the parabola,

$$E - e\sin E = M$$
$$E'' - e\sin E'' = M''$$

In these, of course, $e = [5.314425]\sin\varphi$

Then making $\mu = [3.550007]\,a^{-3/2}$

$$t - T = \frac{M}{\mu} \qquad t'' - T = \frac{M''}{\mu}$$
$$\omega = u - v = u'' - v''.$$

For ellipses nearly parabolic, we can adopt to find the time of perihelion, any process that may be preferred; and for the rare case of the hyperbola, the formulas can be obtained in the *Theoria Motus*.

As an illustration of this method, we will take three observations of Comet *d* 1889, taken from actual work. The places are not very accurate, the first method of Gauss having been used, on the assumption that the distances were well enough known: but they will illustrate the process equally well.

We have then

1889 Gr. M.T.	λ	β	L	log R
	° ′ ″	° ′ ″	° ′ ″	
July 8.9166	353 19 20	—6 50 38	107 20 55	0.007165
23.7347	356 47 0	—6 54 28	121 27 27	.006762
Aug. 19.6825	359 23 58	—6 28 17	147 17 41	0.004940

From these we have

X	+0.147732	$\log Q$	8.719500	$\log B$	9.965312
$\log X''$	9.400899	$\log e$	0.003458	$\log B''$	9.734506
X_0	+0.474603	ζ	—0.310844	C	+0.408053
$\log a$	n8.896187	ζ'	+0.782056	C''	+0.845894
$\log b$	n8.456472	ζ''	—0.901660	$\log\frac{\theta}{\theta''}$	0.260612
$\log P$	n9.202659	$\log\theta'$	9.856091	$\log\theta'\theta''$	9.261584

For the first hypothesis, we assume from a previous parabolic orbit, $\log r = 0.259700$, giving

$\log M = 9.819985$, $n = +0.371456$,
$l = +0.126838$, $N_1 = +0.086438$,
$C''_0 = 1.47234$, $N_2 = +1.463482$,
$v_0 = -0.933780$, $y_0 = +2.58272$.

For $\log X'$ we obtain 9.977801 from the previous orbit, and hence

$$\log m_0 = 1.343875\;; \quad\text{and}\quad Y_0 = 13^\circ\,16'\,40''.$$

The trial-equation then is

$$\sin(Y - 13^\circ\,16'\,40'') = [0.704985]\sin^4 Y$$

This gives $Y = 14^\circ\,23'\,3''$, $y = \sqrt{n}\cot Y = +2.37617$, and $\rho = 1.41269$; the parabolic orbit gives $\rho = 1.706$.

From this we have

$\log r = 0.318706$, $\log rr''\cos 2f' = 0.602963$,
$\log r'' = 0.303995$, $2f' = 17^\circ\,8'\,28''$.

From these,

$\log \eta' = 0.004390$, $f = 5^\circ\,36'\,17''$,
$x' = +0.001881$, $f'' = 2^\circ\,57'\,57''$.

From these, finally, $\log\eta = 0.001862$, $\log\eta'' = 0.000530$; hence, for the next value of r without reduction of times, we have 0.259280.

The reduction of times for the new distances gives for the dates:

July 8.9179, July 23.7363, Aug. 19.6841, the original uncorrected times being July 8.9562, July 23.7437, and Aug. 19.6906. We have then, for the new hypothesis,

$$\log r = 0.259276,\ \log\frac{\theta}{\theta''} = 0.260608,\ \log\theta'\theta'' = 9.261599.$$

And from the present values of r, f, &c., computing first $\log r' = 0.312168$, we have $\log X' = 9.972205$.

For the second hypothesis, then, we have:

$\log r = 0.259276$, $N_1 = +0.086490$,
$\log M = 9.819561$, $N_2 = +1.463968$,
$l = +0.121161$, $y_0 = +2.58017$,
$C''_0 = +1.46518$, $Y_0 = 13^\circ\,22'\,43''.5$,
$v_0 = -0.930212$, $\log m_0 = 1.327002$,
$n = +0.376592$.

The trial-equation is then

$$\sin(Y - 13^\circ\,22'\,43''.5) = [0.691341]\sin^4 Y$$

This gives

$Y = 14^\circ\,28'\,43''$, $y = +2.37655$, $\rho = 1.41631$.

Hence

$\log r = 0.319386$, $f = 5^\circ\,35'\,5''.4$,
$\log r'' = 0.303112$, $f'' = 2^\circ\,56'\,51''.4$,
$2f' = 17^\circ\,3'\,53''$, $\log\eta = 0.001865$,
$\log\eta' = 0.004392$, $\log\eta'' = 0.000529$;
$x' = +0.001921$, hence $\log r = 0.259272$.

Evidently it is not worth while to make a third hypothesis. From $\log\rho = 0.160261$ and $\log(\rho'' = M\rho + l) = 0.031717$ we now compute the plane of the orbit. (It may be here noticed that $\log\frac{\rho''}{\rho}$ from the parabolic orbit was 9.9179, whereas its value is from these results 9.8715; showing that a much better approximation is obtained by taking r instead of $\frac{\rho''}{\rho}$ for our unknown quantity.)

These give $\log r = 0.319385$, $\log r'' = 0.303113$;

also $☊ = 19^\circ\,1'\,1''$, $i = 6^\circ\,1'\,18''$,
$u = 52^\circ\,22'\,29''.5$ $u'' = 35^\circ\,18'\,10''.0$

Hence the accurate value of $2f' = 17^\circ\,3'\,19''.5$.

From this, with r and r'', we compute x' accurately by the formula of Gauss for l,

$$l = \frac{\sin^2\frac{1}{2}f'}{\cos f'} + \frac{\tan^2 2\omega}{\cos f'} \quad \text{in which } \tan(45^\circ - \omega) = \text{[illegible]}$$

We have $x' = +0.00192061$, which gives
$\log e = 9.702387$, $\log a = 0.603853$, $\omega = 337° 40' 8''$,
$T =$ Sept. 19.0592 G.M.T., and the period 2940 days.

The middle place gives. (O—C):

$$\Delta\lambda = -1'' \qquad \Delta\beta = 0''$$

For an example of the parabolic formulas, we will take three observations of Comet *b* 1889, made at Mt. Hamilton.

Reduced to latitude and longitude, 1889.0, and corrected for aberration, we have

Greenw. M.T.	λ	β	L	log R
	° ′ ″	° ′ ″	° ′ ″	
April 16.6703	78 8 13	—7 22 31	27 20 9	0.001930
21.6748	77 42 8	—7 29 42	32 12 57	.002531
26.6848	77 22 59	—7 37 11	37 5 24	0.003115

Assuming $M = \frac{N}{N''} \cdot \frac{b}{a}$, we have for log *M*, 0.024369.

$$\log c = 0.333556, \qquad \log n = 9.679185,$$
$$\log e = 0.007419, \qquad \log i = 7.5635,$$
$$g^2 = 0.029258, \qquad d = -3.0388,$$
$$\rho_0 = +0.670010, \qquad \log 2\theta'^2 = 8.77345.$$

Putting first $\kappa^2 r_1 = 2\theta'^2$ and solving approximately, we have $\log \sec f' = 0.00028$ and $\log N = 0.00024$; these values can be used for the complete solution.

For $N\kappa^2 r_{\text{ii}} = 2\theta'^2$, we have $\rho = 2.7364$. From this we obtain

$$\log r = 0.355820, \qquad u = 215° \; 6' \, 32'',$$
$$\log r'' = 0.353550, \qquad u'' = 219° \, 11' \, 56'',$$
$$\Omega = 312° \, 32' \, 44'', \qquad 2f' = 4° \; 5' \, 24''.$$
$$i = 164° \, 15' \; 2''.$$

Hence $v = -10° \, 25' \, 19''$, $\log q = 0.352222$,
$v'' = -\; 6° \, 19' \, 55''$, and $T =$ May 12.0495.

These elements represent the middle place as follows, (O—C):

$$\Delta\lambda = +5'' \qquad \Delta\beta = 0''$$

The times have not been corrected for planetary aberration; but this is unnecessary, as our only object is to show the working of the method.

If η' is computed by the formulas of Gauss, it may be well to substitute for the table giving log . *yy* for argument *h*, one giving *h* — log *yy*, as the differences for this table are smaller, and the interpolation easier. Such a table is of course very easily constructed.

ELEMENTS AND EPHEMERIS OF COMET *f* 1889,

By Rev. GEORGE M. SEARLE.

I have computed, by the portion of the above method adapted to the case of a parabolic orbit, the following elements for comet *f* 1889 (Swift) from two observations, November 18 and 22, kindly furnished by Mr. Wendell, (by permission of Prof. Pickering of Harvard College Observatory), together with one of November 20 telegraphed from Mt. Hamilton.

$$T = 1889 \text{ Dec. } 1.6136 \text{ Gr. M.T.}$$
$$\left.\begin{aligned} \Omega &= 324° \; 48' \; 54'' \\ \omega &= 74 \;\; 17 \;\; 48 \\ i &= 10 \;\; 58 \;\; 14 \end{aligned}\right\} 1889.0$$
$$\log q = 0.155149$$

Middle place (O—C) $\Delta\lambda = +28''$, $\Delta\beta = -3''$

The small inclination gives considerable probability of periodicity; the sign of the discordance for the middle place also seems to point the same way.

These elements give the following ephemeris for Greenwich midnight, 1889.0.

1889	App. α	App. δ	log Δ	Br.
	h m s	° ′		
Nov. 26	23 3 3	+14 28.4	9.8979	0.96
30	13 25	15 40.3	.9041	.94
Dec. 4	24 28	16 51.9	.9110	.91
8	36 9	18 3.4	.9188	.87
12	23 48 25	19 14.0	.9274	.83
16	0 1 13	+20 22.8	9.9368	0.79

OBSERVATIONS OF COMET *d* 1889,

MADE AT THE U.S. NAVAL OBSERVATORY WITH THE 9.6-INCH EQUATORIAL,

By Prof. E. FRISBY.

1889 Washington M.T.	*	No. Comp.	☄ — *		☄'s apparent		log *p*Δ	
			Δα	Δδ	α	δ	for α	for δ
d h m s			m s	′ ″	h m s	° ′ ″		
Nov. 16 8 56 56.2	1	20 , 4	—0 35.22	—0 31.0	23 48 32.73	—0 30 45.7	9.030	0.746
19 7 56 16.1	2	19 , 4	—0 6.32	+3 8.1	23 50 41.45	—0 4 46.4	7.709	0.743

Mean Places for 1889.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	23 49 5.72	+2.23	—0 30 29.6	+14.9	½(Yarnall + Grant)
2	23 50 45.47	+2.20	—0 8 9.2	+14.7	Rümker 11772

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THE ORBIT OF SWIFT'S COMET 1880 V, DETERMINED BY GIBBS'S VECTOR METHOD.*

By W. BEEBE and A. W. PHILLIPS.

The orbit of SWIFT's comet (1880 V) is a very critical one when computed from the three observations used in this paper. During the period between the two extreme dates the comet remained near opposition, moving almost parallel with the earth, and at a distance from it of from twelve to fifteen million of miles.

In computing this orbit, we have pursued the plan of calculating the elliptic elements directly from the observations without the aid of a preliminary parabolic orbit or any previous determination of the comet's heliocentric distance and motion. Evidently this affords a more severe test of the efficiency of the method.

The motion between the three positions is expressed in terms including the fourth powers of the time; and therefore the constants in the fundamental equation connecting the heliocentric and geocentric distances of the comet are determined with great accuracy. In GAUSS's method the corresponding motion is expressed in terms including nothing beyond the second powers of the time. In employing OPPOLZER's method we have found that the constants of the fundamental equation are not determined with sufficient precision to enable us to obtain a solution directly from these observations. It should be said that, in general, on account of this accurate method of obtaining these constants in GIBBS's fundamental equation, the successive hypotheses will give better results than are obtained at corresponding stages of the work by the methods of GAUSS and OPPOLZER. The labor also of preparing the fundamental equation for solution is much less in GIBBS's method than in either of the two others.

Again, the formulas for the correction of the assumed values, in the successive approximations in each hypothesis, include terms of a higher order than are retained by GAUSS or OPPOLZER, and consequently the convergence in these approximations is more rapid.

Another feature of GIBBS's method which deserves special mention, is the great simplicity which characterizes the development of the fundamental equation. The various artifices employed in the solution in no way obscure the essential features of the theory.

THE FUNDAMENTAL EQUATION.

The motion between the three given positions of a comet may be expressed with a high degree of accuracy by an equation of the form

$$R = A + B\tau + C\tau^2 + D\tau^3 + E\tau^4$$

where R denotes a vector† drawn from the sun to any given

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* *Memoirs of the National Academy*, Vol. IV, p. 81 ff.

† The following note is taken from *Mem. Nat. Acad.*, Vol. IV, pages 81 and 82

Vectors, or *directed quantities*, will be represented in this paper by German capitals. The following notations will be used in connection with them.

The sign = denotes identity in direction as well as length.

The sign + denotes geometrical addition, or what is called composition in mechanics

The sign — denotes reversal of direction, or composition after reversal

The notation $\mathfrak{A} \cdot \mathfrak{B}$ denotes the product of the lengths of the vectors and the cosine of the angle which they include. It will be called the *direct product* of $\mathfrak{A}$ and $\mathfrak{B}$. If x, y, z are the rectangular components of $\mathfrak{A}$, and x', y', z' those of $\mathfrak{B}$

$$\mathfrak{A} \cdot \mathfrak{B} = xx' + yy' + zz'.$$

$\mathfrak{A} \cdot \mathfrak{A}$ may be written $\mathfrak{A}^2$ and called the square of $\mathfrak{A}$.

The notation $\mathfrak{A} \times \mathfrak{B}$ will be used to denote a vector of which the length is the product of the lengths of $\mathfrak{A}$ and $\mathfrak{B}$ and the sine of the angle which they include. Its direction is perpendicular to $\mathfrak{A}$ and $\mathfrak{B}$ and on that side on which a rotation from $\mathfrak{A}$ to $\mathfrak{B}$ appears counter-clock-wise. It will be called the *skew product* of $\mathfrak{A}$ and $\mathfrak{B}$. If the rectangular components of $\mathfrak{A}$ and $\mathfrak{B}$ are x, y, z, and x', y', z', those of $\mathfrak{A} \times \mathfrak{B}$ will be

$$yz' - zy', \qquad zx' - xz', \qquad xy' - yx'.$$

position of the comet (r will be used to denote the length of this vector) A, B, C, D, E, vector constants, and τ the interval of time between two successive positions of the comet multiplied by k, the attractive force of the sun.

The actual motion rigorously satisfies six conditions. If we put in succession $\tau = -\tau_3, o, \tau_1$ and $R = R_1, R_2, R_3$ and again for the same values of τ

$$\frac{d^2R}{d\tau} = -\frac{\overline{R}_1}{r^3_1}, -\frac{R_2}{r^3_2}, -\frac{\overline{R}_3}{r^3_3}$$

we obtain six equations, from which the five constants A, B, C, D, E may be eliminated, leaving a single equation of the form

$$(1) \qquad A_1\left(1+\frac{B_1}{r^3_1}\right)R_1 - \left(1-\frac{B}{r^3_2}\right)R_2 + A_3\left(1+\frac{B_3}{r^3_1}\right)R_3 = 0$$

where $A_1 = \dfrac{\tau_1}{\tau_1+\tau_3}$ $\qquad A_3 = \dfrac{\tau_3}{\tau_1+\tau_3}$

$$B_1 = \tfrac{1}{12}(-\tau^2_1+\tau_1\tau_3+\tau^2_3) \qquad B_2 = \tfrac{1}{12}(\tau^2_1+3\tau_1\tau_3+\tau^2_3)$$

$$B_3 = \tfrac{1}{12}(\tau_1^2+\tau_1\tau_3-\tau^2_3)$$

Equation (1) is called the fundamental equation, and signifies that the three vectors $\overline{R}_1$, $\overline{R}_2$, $\overline{R}_3$, lie in one plane, and that the three triangles, determined each by a pair of these vectors, and ordinarily denoted by $[r_2r_3]$, $[r_1r_3]$, $[r_1r_2]$ are proportional to their coefficients.

Let $\overline{E}_1\ \overline{E}_2\ \overline{E}_3$ represent vectors drawn from the sun to the earth (observatory).

$\overline{F}_1\ \overline{F}_2\ \overline{F}_3$ unit vectors drawn in the direction of the comet as observed.

$\rho_1\ \rho_2\ \rho_3$ the distances of the comet from the places of observation.

We have then

$$\overline{R}_1 = \overline{E}_1 + \rho_1\overline{F}_1 \qquad \overline{R}_2 = \overline{E}_2 + \rho_2\overline{F}_2 \qquad \overline{R}_3 = \overline{E}_3 + \rho_3\overline{F}_3$$

Substituting these values, the fundamental equation becomes

$$A_1\left(1+\frac{B_1}{r^3_1}\right)(\overline{E}_1+\rho_1\overline{F}_1) - \left(1-\frac{B_2}{r^3_2}\right)(\overline{E}_2+\rho_2\overline{F}_2) + A_3\left(1+\frac{B_3}{r_3^3}\right)(\overline{E}_3+\rho_3\overline{F}_3) = 0$$

From these vector-equations the values of $r_1\ r_2\ r_3$ and $\rho_1\ \rho_2\ \rho_3$ may be derived by successive approximation.

OBSERVATIONS — WASHINGTON TRANSIT.

1880.0

Washington M.T.	α	δ
	° ′ ″	° ′ ″
1880 Oct. 25.313242	327 31 17.2	28 28 31.1
38.315808	341 15 35.5	42 25 29.7
51.377642	16 23 9.4	54 20 57.3

These observations are corrected for precession, nutation and aberration of fixed stars; but the times are not corrected for aberration.

PRELIMINARY CALCULATIONS RELATING TO THE TIME-INTERVALS.

$\log k$ 8.2355814 (after GAUSS)

$\log\tau_1 = 9.3515856 \qquad \log\tau_3 = 9.3496105$

$\log A_1 = 9.6999565 \qquad \log A_3 = 9.6979814$

$\log B_1 = 7.6180465 \quad \log B_2 = 8.3209867 \quad \log B_3 = 7.6259172$

Control $\quad A_1B_1 + B_2 + A_3B_3 = \frac{1}{3}\tau_1\tau_3$

PRELIMINARY CALCULATIONS RELATING TO THE POSITIONS OF THE EARTH AND COMET.

Components of $\overline{E}_1\ \overline{E}_2\ \overline{E}_3$

$\log X_1$	9.9208294	$\log X_2$	9.8373872	$\log X_3$	9.7040607
$\log Y_1$	9.6956173	$\log Y_2$	9.8153054	$\log Y_3$	9.8909060
$\log Z_1$	9.3330498	$\log Z_2$	9.4527117	$\log Z_3$	9.5282969

Components of $\overline{F}_1\ \overline{F}_2\ \overline{F}_3$

$\log\xi_1$	9.8701325	$\log\xi_2$	9.8444950	$\log\xi_3$	9.7475436
$\log\eta_1$	n9.6739610	$\log\eta_2$	n9.3750306	$\log\eta_3$	9.2159641
$\log\zeta_1$	9.6783191	$\log\zeta_2$	9.8290614	$\log\zeta_3$	9.9098687

For each of the three observations we have

$$E^2 = X^2+Y^2+Z^2 \qquad \overline{E}.\overline{F} = X\xi + Y\eta + Z\zeta$$

$$p^2 = E^2 - (\overline{E}.\overline{F})$$

In the last equation p is the perpendicular from the sun

The notation $(\mathfrak{A}\mathfrak{B}\mathfrak{C})$ denotes the volume of the parallelopiped of which three edges are obtained by laying off the vectors $\mathfrak{A}$, $\mathfrak{B}$, and $\mathfrak{C}$ from any same point, which volume is to be taken positively or negatively, according as the vector $\mathfrak{C}$ falls on the side of the plane containing $\mathfrak{A}$ and $\mathfrak{B}$, on which a rotation from $\mathfrak{A}$ to $\mathfrak{B}$ appears counter-clock-wise, or on the other side. If the rectangular components of $\mathfrak{A}$, $\mathfrak{B}$, and $\mathfrak{C}$ are x, y, z; x', y', z'; and x'', y'', z'',

$$(\mathfrak{A}\mathfrak{B}\mathfrak{C}) = \begin{vmatrix} x & y & z \\ x' & y' & z' \\ x'' & y'' & z'' \end{vmatrix}$$

It follows, from the above definitions, that for any vectors $\mathfrak{A}$, $\mathfrak{B}$, and $\mathfrak{C}$

$$\mathfrak{A}\cdot\mathfrak{B} = \mathfrak{B}\cdot\mathfrak{A}, \qquad \mathfrak{A}\times\mathfrak{B} = -\mathfrak{B}\times\mathfrak{A}, \qquad (\mathfrak{A}\mathfrak{B}\mathfrak{C}) = (\mathfrak{B}\mathfrak{C}\mathfrak{A}) = (\mathfrak{C}\mathfrak{A}\mathfrak{B}) = -(\mathfrak{A}\mathfrak{C}\mathfrak{B}) = -(\mathfrak{C}\mathfrak{B}\mathfrak{A}) = -(\mathfrak{B}\mathfrak{A}\mathfrak{C}),$$

and

$$(\mathfrak{A}\mathfrak{B}\mathfrak{C}) = \mathfrak{A}\cdot(\mathfrak{B}\times\mathfrak{C}) = \mathfrak{B}\cdot(\mathfrak{C}\times\mathfrak{A}) = \mathfrak{C}\cdot(\mathfrak{A}\times\mathfrak{B}):$$

also that $\mathfrak{A}\cdot\mathfrak{B}$, $\mathfrak{A}\times\mathfrak{B}$, are distributive functions of $\mathfrak{A}$ and $\mathfrak{B}$, and $(\mathfrak{A}\mathfrak{B}\mathfrak{C})$ a distributive function of $\mathfrak{A}$, $\mathfrak{B}$, and $\mathfrak{C}$, for example, that if $\mathfrak{A} = \mathfrak{L} + \mathfrak{M}$,

$$\mathfrak{A}\cdot\mathfrak{B} = \mathfrak{L}\cdot\mathfrak{B} + \mathfrak{M}\cdot\mathfrak{B}, \qquad \mathfrak{A}\times\mathfrak{B} = \mathfrak{L}\times\mathfrak{B} + \mathfrak{M}\times\mathfrak{B}, \qquad (\mathfrak{A}\mathfrak{B}\mathfrak{C}) = (\mathfrak{L}\mathfrak{B}\mathfrak{C}) + (\mathfrak{M}\mathfrak{B}\mathfrak{C}),$$

and so for $\mathfrak{B}$ and $\mathfrak{C}$.

The notation $(\mathfrak{A}\mathfrak{B}\mathfrak{C})$ is identical with that of LAGRANGE in the *Mécanique Analytique*, except that there its use is limited to unit vectors. The signification of $\mathfrak{A}\times\mathfrak{B}$ is closely related to, but not identical with, that of the notation $[r_1r_2]$ commonly used to denote the double area of a triangle determined by two positions in an orbit.

on the line of sight. We shall represent also by q the distance of the comet from the foot of this perpendicular.

$\log E^2_1$	9.9943188	$\log E^2_2$	9.9914549	$\log E^2_3$	9.9889723
$\log E_1F_1$	9.6870106	$\log E_2F_2$	9.7135182	$\log E_3F_3$	9.8357180
$\log p^2_1$	9.8752929	$\log p^2_2$	9.8532073	$\log p^2_3$	9.7038112

We shall also have

$$q = \rho + (E\,.\,F) \qquad r^2 = p^2 + q^2$$

Equation (1) may be written

$$S_1 + S_2 + S_3 = 0 \qquad \text{where}$$

$$S_1 = A_1\left(1+\frac{B_1}{r^3_1}\right)(E_1+\rho_1 F_1) \qquad S_2 = -\left(1-\frac{B_2}{r^3_2}\right)(E_2+\rho_2 F_2)$$

$$S_3 = A_3\left(1+\frac{B_3}{r^3_3}\right)(E_3+\rho_3 F_3)$$

Since equation (1) is not rigorously satisfied by the *assumed* values of the unknown quantities, let us put

$$S = S_1 + S_2 + S_3$$

When equation (1) is satisfied S becomes zero. Differentiating.

$$dS = S'\,dq_1 + S''.\,dq_2 + S'''\,dq_3 \qquad (2)$$

where $$S' = \frac{dS_1}{dq_1} = A_1\left(1+\frac{B_1}{r^3_1}\right)F_1 - A_1\frac{3B_1}{r^4_1}\frac{q_1}{r_1}\left(E_1+\rho_1 F_1\right)$$

S'' and S''' may be expressed in a similar form.

Equations of the First Hypothesis.

$$\text{Components of } S_1 \begin{cases} \alpha_1 = A_1\,\xi_1(1+R_1)\left(q_1+\frac{X_1}{\xi_1}-(E_1\cdot F_1)\right) = [\;9.5700890](1+R_1)(q_1+0.6374005) \\ \beta_1 = A_1\,\eta_1(1+R_1)\left(q_1+\frac{Y_1}{\eta_1}-(E_1\cdot F_1)\right) = [n9.3739135](1+R_1)(q_1-1.5375496) \\ \gamma_1 = A_1\,\zeta_1(1+R_1)\left(q_1+\frac{Z_1}{\zeta_1}-(E_1\cdot F_1)\right) = [\;9.3782756](1+R_1)(q_1-0.0348441) \end{cases}$$

where $q_1 = \rho_1 + E_1\cdot F_1 = \rho_1 + .4861199 \qquad r_1^2 = q_1^2 + p_1^2 = q_1^2 + .7504001 \qquad R_1 = B_1r_1^{-3} = [7.6180465]\,r_1^{-3}$

For control $$s_1^2 = \alpha_1^2 + \beta_1^2 + \gamma_1^2 = A_1^2(1+R_1)^2r_1^2$$

$$\text{Components of } S' \begin{cases} \alpha' = A_1\,\xi_1 + A_1\,\xi_1\,R_1 - P'\alpha' = \;\;0.3716114 + [\;9.5700890]\,R_1 - P'\alpha_1 \\ \beta' = A_1\,\eta_1 + A_1\,\eta_1\,R_1 - P'\beta' = -0.2365470 + [n9.3739175]\,R_1 - P'\beta_1 \\ \gamma' = A_1\,\zeta_1 + A_1\,\zeta_1\,R_1 - P'\gamma' = \;\;0.2389327 + [\;9.3782756]\,R_1 - P'\gamma_1 \end{cases}$$

where $$P' = \frac{3R_1q_1}{(1+R_1)r_1^2}$$

$$\text{Components of } S_2 \begin{cases} \alpha_2 = -\xi_2(1-R_2)\left(q_2+\frac{X_2}{\xi_2}-(E_2\cdot F_2)\right) = [\;9.8144950](1-R_2)(q_2+0.4667338) \\ \beta_2 = -\eta_2(1-R_2)\left(q_2+\frac{Y_2}{\eta_2}-(E_2\cdot F_2)\right) = [\;9.3750306](1-R_2)(q_2-3.273005) \\ \gamma_2 = -\zeta_2(1-R_2)\left(q_2+\frac{Z_2}{\zeta_2}-(E_2\cdot F_2)\right) = [n9.8290611](1-R_2)(q_2-0.096645) \end{cases}$$

where $q_2 = \rho_2 + (E_2\cdot F_2) = \rho_2 + .5170330 \qquad r_2^2 = q_2^2 + q_2^2 = q_2^2 + .7131931 \qquad R_2 = B_2r_2^{-3} = [8.3209867]\,r_2^{-3}$

For control $$s_2^2 = \alpha_2^2 + \beta_2^2 + \gamma_2^2 = (1-R_2)^2\,r_2^2.$$

$$\text{Components of } S'' \begin{cases} \alpha'' = -\xi_2 + \xi_2\,R_2 + P''\alpha_2 = -0.6990287 + [\;9.8444950]\,R_2 + P''\alpha_2 \\ \beta'' = -\eta_2 + \eta_2\,R_2 + P''\beta_2 = \;\;0.2371541 + [n9.3750306]\,R_2 + P''\beta_2 \\ \gamma'' = -\zeta_2 + \zeta_2\,R_2 + P''\gamma_2 = -0.6746234 + [\;9.8290611]\,R_2 + P''\gamma_2 \end{cases}$$

where $$P'' = \frac{3R_2q_2}{(1-R_2)r^2_2}$$

$$\text{Components of } S_3 \begin{cases} \alpha_3 = A_3\,\xi_3(1+R_3)\left(q_3+\frac{X_3}{\xi_3}-(E_3\cdot F_3)\right) = [9.4455250](1+R_3)(q_3+0.2196827) \\ \beta_3 = A_3\,\eta_3(1+R_3)\left(q_3+\frac{Y_3}{\eta_3}-(E_3\cdot F_3)\right) = [8.9139155](1+R_3)(q_3+4.0158360) \\ \gamma_3 = A_3\,\zeta_3(1+R_3)\left(q_3+\frac{Z_3}{\zeta_3}-(E_3\cdot F_3)\right) = [9.6078501](1+R_3)(q_3-0.2696800) \end{cases}$$

where $q_3 = \rho_3 + (E_3\cdot F_3) = \rho_3 + .6850133 \qquad r_3^2 = q_3^2 + p_3^2 = q_3^2 + .5056133 \qquad R_3 = B_3r_3^{-3} = [7.6259172]\,r_3^{-3}$

For control $$s_3^2 = \alpha_3^2 + \beta_3^2 + \gamma_3^2 = A_3^2(1+R_3)^2r_3^2$$

$$\text{Components of } S''' \begin{cases} \alpha.''' = A_3\,\xi_3 + A_3\,\xi_3\,R_3 - P'''\alpha_3 = 0.2789491 + [9.4455250]\,R_3 - P'''\alpha_3 \\ \beta''' = A_3\,\eta_3 + A_3\,\eta_3\,R_3 - P'''\beta_3 = 0.0820249 + [8.9139155]\,R_3 - P'''\beta_3 \\ \gamma''' = A_3\,\zeta_3 + A_3\,\zeta_3\,R_3 - P'''\gamma_3 = 0.1053686 + [9.6078501]\,R_3 - P'''\gamma_3 \end{cases}$$

where $$P''' = \frac{3R_3q_3}{(1+R_3)r^2_3}$$

We will now assume, as a first approximation, for the distances from the earth to the comet at the three times of observation

$$\rho_1 = \rho_2 = \rho_3 = 0.25$$

and, substituting in the several equations above, we obtain the numbers in the first column of each of the following tables.

From the observed positions and motion of the comet, we should be warranted in assuming a much smaller value, which would make the approximation more rapid.

$\Delta q_1 = \Delta\rho_1$		—0.0890	—0.00360	0.002325	—0.000091
ρ_1	0.250	0.1610	.15740	.159725	.159361
q_1	.73642	.647120	.643820	.6461449	.6460509
r_1^2	1.29272	1.169552	1.161904	1.1679033	1.1677818
R_1	.00282	.003281	.003301	.0032880	.0032885
$\log P'$	7.68231		7.736776		
α_1	0.51198	0.479020	0.477688	0.4785481	
β_1	.19004	.211249	.212107	.2115528	
γ_1	.16811	.146815	.145985	.1465400	
$\log \alpha'$	9.56844		9.568474		
$\log \beta'$	n9.37681		n9.377461		
$\log \gamma'$	9.37803		9.378262		
$\Delta\rho_2$		—0.1229	0.00132	0.001518	—0.000072
ρ_2	0.250	.1271	.13142	.132938	.132866
q_2	.76703	.614133	.648153	.6499710	.6498990
r^2_2	1.30152	1.128101	1.133681	1.1356557	1.1355620
R_2	.01410	.017477	.017348	.0173028	.0173050
$\log P''$	8.40297		8.481357		
α_2	—0.85026	—0.762955	—0.766025	—0.7671018	
β_2	—0.58592	—0.612551	—0.611626	—0.6112996	
γ_2	—0.44588	—0.362892	—0.365804	—0.3668277	
$\log \alpha''$	n9.85167		n9.851324		
$\log \beta''$	9.34012		9.331450		
$\log \gamma''$	n9.83020		n9.828661		
$\Delta\rho_3$		—0.1314	0.00632	0.001318	—0.000064
ρ_3	0.250	.1186	.12492	.126238	.126174
q_3	.93501	.803643	.809963	.8112813	.8112173
r^2_3	1.37994	1.151485	1.161683	1.1638207	1.1637167
R_3	.00261	.003420	.003375	.0033660	.0033665
P'''	7.72312		7.847349		
α_3	0.32295	0.286432	0.288189	0.2885545	
β_3	0.40962	0.399139	0.399612	0.3997454	
γ_2	0.27042	0.217192	0.219753	0.2202872	
$\log \alpha'''$	9.14400		9.143830		
$\log \beta'''$	8.90347		8.900311		
$\log \gamma'''$	9.60746		9.607659		

To obtain Δq, the correction of the geocentric distance, we apply equation (2) to these finite differences, and have approximately

$$-\bar{S} = S'\Delta q_1 + \bar{S}''\Delta q_2 + S'''\Delta q_3 \tag{3}$$

whence

$$\Delta q_1 = -\frac{\bar{S}\cdot\bar{S}''\times S'''}{S'\cdot S''\times S'''} \qquad \Delta q_2 = -\frac{\bar{S}\cdot S'''\times S'}{\bar{S}'\cdot S''\times S'''} \qquad \Delta q_3 = -\frac{S\cdot S'\times\bar{S}''}{S'\cdot\bar{S}''\times\bar{S}'''}$$

Components of S	Components of $\bar{S}''\times S'''$	Components of $\bar{S}'''\times\bar{S}'$	Components of $\bar{S}'\times S''$
$\alpha = \alpha_1 + \alpha_2 + \alpha_3$	$a_1 = \beta''\gamma''' - \gamma''\beta'''$	$a_2 = \beta'''\gamma' - \gamma'''\beta'$	$a_3 = \beta'\gamma'' - \gamma'\beta''$
$\beta = \beta_1 + \beta_2 + \beta_3$	$b_1 = \gamma''\alpha''' - \alpha''\gamma'''$	$b_2 = \gamma'''\alpha' - \alpha'''\gamma'$	$b_3 = \gamma'\alpha'' - \alpha'\gamma''$
$\gamma = \gamma_1 + \gamma_2 + \gamma_3$	$c_1 = \alpha''\beta''' - \beta''\alpha'''$	$c_2 = \alpha'''\beta' - \beta'''\alpha'$	$c_3 = \alpha'\beta'' - \beta'\alpha''$

Put $$G = \bar{S}'\,.\,S''\times\bar{S}''' = a_1\alpha' + b_1\beta' + c_1\gamma' = a_2\alpha'' + b_2\beta'' + c_2\gamma'' = a_3\alpha''' + b_3\beta''' + c_3\gamma'''$$

In the case of a critical orbit like the present one, more complete values would be obtained from equation (5) by adding terms involving second differential coefficients according to Taylor's theorem. This will give approximately,

$$\Delta q_2 = C'_2 - \tfrac{6}{15} L(\Delta q_2)^2 \qquad \Delta q_1 = C'_1 - \tfrac{6}{15} L(\Delta q_1)^2 \qquad \Delta q_3 = C'_3 - \tfrac{6}{15} L(\Delta q_3)^2$$

where

$$C'_2 = \frac{a_2\alpha + b_2\beta + c_2\gamma}{G} \qquad C'_1 = \frac{a_1\alpha + b_1\beta + c_1\gamma}{G} \qquad C'_3 = \frac{a_3\alpha + b_3\beta + c_3\gamma}{G}$$

$$L = \frac{1}{q_2}\left(1 + \frac{H}{G}\right)\left(1 - 5\frac{q_2^2}{r_2^2}\right) - \frac{R_2 H}{q_2 G}\left(1 + \frac{q_2^2}{r_2^2}\right) \qquad H = F_2 \cdot S''' \times S' = a_2\xi_2 + b_2\eta_2 + c_2\zeta_2$$

CORRECTION OF GEOCENTRIC DISTANCES FOR THE SECOND APPROXIMATION.

From the values of α', β', &c., in the first column of each of the above tables, we obtain

$\log a_1$ 9.15488	$\log a_2$ 9.06282	$\log a_3$ 9.03653
$\log b_1$ 8.99917	$\log b_2$ 8.92197	$\log b_3$ 8.90685
$\log c_1$ n9.07106	$\log c_2$ n8.98152	$\log c_3$ n8.94528

We obtain three values of G nearly identical. Adopting the mean we write

$$\log G \quad 6.99647.$$

The three components of the residual S are

$$\alpha = -0.01533 \qquad \beta = 0.01371 \qquad \gamma = -0.00735$$

From these, with the numbers last computed, we find

$$C'_1 = -0.0475982 \qquad C'_2 = -0.0815662 \qquad C'_3 = -0.0900285$$

We also compute

$$\log H \quad n7.56632 \qquad \log L \quad 0.65919$$

Hence

$$\Delta q_2 = -0.1229 \qquad \Delta q_1 = -0.0890 \qquad \Delta q_3 = -0.1314$$

With these three values of Δq we commence the second column in each of the preceding tables.

(Continued in the next number.)

OBSERVATIONS OF COMET *d* 1889 (*BROOKS, July 6*),

MADE AT THE HALSTED OBSERVATORY, PRINCETON, N. J., WITH THE 23-INCH EQUATORIAL AND THE SQUARE-BAR MICROMETER.

By PROF. C. A. YOUNG AND D. C. MILLER.

[Communicated by Professor. YOUNG.]

1889 Eastern Standard Time. = G.M.T. − 5ʰ	*	No. Comp.	☌ − * Δα	☌ − * Δδ	☌'s apparent α	☌'s apparent δ	log pΔ for α	log pΔ for δ	Obs.
d h m s			m s	′ ″	h m s	° ′ ″			
Nov. 14 9 10 6	1	9	−1 58.56	+5 39.6	23 47 13.95	−0 47 57.9	9.0751	0.7598	Y
9 49 5	1	6	−1 57.84	+5 55.1	23 47 15.67	−0 47 42.1	9.2794	0.7609	M
15 7 26 21	2	13	−1 17.55	−9 57.7	23 47 50.51	−0 40 10.6	n8.8805	0.7590	Y
8 15 0	2	11	−1 16.83	−9 40.7	23 47 51.23	−0 39 53.6	8.2726	0.7589	M
16 7 25 23	2	10	−0 37.78	−1 18.8	23 48 30.26	−0 31 31.8	n8.8544	0.7577	M
7 59 7	2	10	−0 36.62	−1 5.5	23 48 31.12	−0 31 18.5	n7.7675	0.7575	M
8 22 27	2	9	−0 35.81	−0 54.1	23 48 32.20	−0 31 7.1	8.5995	0.7575	M
23 8 40 21	3	7	−0 23.45	+3 20.9	23 53 57.82	+0 31 51.7	n9.068	0.718	M
8 58 15	3	8	−0 22.88	+3 27.4	23 53 58.39	+0 31 58.2	n9.177	0.718	M
9 20 21	3	10	−0 21.97	+3 38.0	23 53 59.30	+0 32 8.8	n9.280	0.719	M
25 8 16 9	4	5	+1 16.22	+7 38.1	23 55 13.91	+0 50 41.9	n9.111	0.717	M
9 54 38	4	6	+1 18.76	+8 8.2	23 55 16.15	+0 51 12.0	n9.412	0.717	M
26 7 12 52	5	10	−1 21.31	+1 20.1	23 56 35.68	+0 59 38.9	8.543	0.711	M

Mean Places for 1889.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place.	Authority
	h m s	s	° ′ ″	″	
1	23 49 10.21	+2.30	−0 53 52.8	+15.3	Yarnall 10847
2	23 49 5.81	+2.25	−0 30 28.1	+15.2	½(Yarnall 10846 + Gr. 9 yr. 1872)
3	23 51 19.08	+2.19	+0 28 16.3	+11.1	Yarnall 10895 [Vol. LXIII, p. 87
4	23 51 25.51	+2.18	+0 12 49.3	+11.5	Vienna Merid. Observ., *As. Nachr.*
5	23 57 57.79	+2.20	+0 58 1.1	+11.1	Yarnall 10926

The above places are corrected for proper motion, instrumental errors and refraction, but not for aberration or parallax. The power used was 110. On Nov. 14 both observers saw the companion-comet, about 5′ from the principal comet, at a position-angle of between 50° and 60°. It was still better seen on the 15th by Mr. MILLER, but not quite well enough to admit of observation on the bars. The main comet was decidedly elongated by a short brush 1′.5 in length directed nearly toward the companion.

The comet was easily observable on all the last three nights. Except that on Nov. 25, the observations were somewhat interfered with by flying clouds. On account of bad weather and moonlight it has not been possible to obtain other observations up to date.

Princeton, N. J., 1889 *Dec.* 7.

OBSERVATIONS OF SOME SUSPECTED VARIABLES,

By Rev. JOHN G. HAGEN, S.J., Georgetown College.

I. Lal. 26980 = 14h 42m.7 +6° 28′.9 (1875.0). This star is one of the list published in Vol. XIV of the Annals of Harvard College Observatory, p. 176, and marked H.P. 2475. I continued the observations for four years more, using the same comparison-stars and the same scale as in Table LVII of the above publication, with the negative result that there is no proof of variation between the years 1884–1889. In fact 16 observations, made with a large opera-glass during 1884, constantly give its magnitude 6.8 and 6.9, whilst a smaller glass which I used during the following four years give a slight variation of magnitude, due, however, as I certified, to the position-angle of the constellation, the star appearing fainter during spring in the east and brighter during autumn in the west. There are on an average 15 observations a year, and taking the mean of the last 4 years by months we have, with an extreme range of less than 0.2 of a magnitude:

March, 3 comparisons, magnitude 6.80
April, 7 " " 6.83
May, 17 " " 6.80
June, 12 " " 6.70
July, 8 comparisons, magnitude 6.66
Aug., 10 " " 6.65
Sept., 4 " " 6.70

II. In the year 1886 I compared a portion of the Milky Way with Argelander's charts according to a plan proposed by Prof. Pickering in an article "Variable Stars of Short Period (*Proc. Amer. Acad., Vol. XVI*), which showed that the variable stars of the β *Lyrae* type are arranged in a great circle whose pole is 13h, +20° with an average deviation of not more than 5°. *Three* stars were found that showed rather a large difference from the DM. magnitudes and were watched from 1886 to 1889. Although no variation was noticed during these three years, the fact that they differ from the Bonn DM. may be worth putting on record.

The following means were deduced from the DM. magnitudes of neighboring stars with the mean deviation of the single observations:

DM. 55°.2587, mean of 10 obs. = 7M.8 ±0M.1; DM. = 8M.8
DM. 41.3368, " " 7 " = 7.6 ±0.1; " = 7.0
DM. 44.3402, " " 7 " = 7.7 ±0.0; " = 8.1

EPHEMERIS OF COMET *d* 1889.

(Continued from page 104.)

890 Gr. M.T.	App. α	App. δ	log r	log Δ	Br.
	h m s	° ′			
Jan. 0.5	0 39 56	+7 8.6			
1.5	41 26	19.8			
2.5	42 56	31.0	0.3229	0.2686	
3.5	44 27	42.2			
4.5	45 58	7 53.4			
5.5	47 30	8 4.7	0.3248	0.2782	
6.5	49 2	16.0			
7.5	50 36	17.2			
8.5	52 9	38.5	0.3267	0.2876	0.56
9.5	53 44	8 49.8			
10.5	55 19	9 1.0			
11.5	56 54	12.3	0.3287	0.2969	
12.5	0 58 30	23.6			
13.5	1 0 6	+9 34.9			
Jan. 14.5	1 1 43	+ 9 46.2	0.3307	0.3061	
15.5	3 20	9 57.4			
16.5	4 58	10 8.7			
17.5	6 36	20.0	0.3327	0.3151	0.48
18.5	8 15	31.2			
19.5	9 55	42.5			
20.5	11 34	10 53.7	0.3348	0.3240	
21.5	13 14	11 4.9			
22.5	14 55	16.1			
23.5	16 36	27.3	0.3369	0.3327	
24.5	18 18	38.5			
25.5	20 0	11 49.6			
26.5	1 21 42	+12 0.8	0.3390	0.3413	0.41

EPHEMERIS OF COMET *f* 1889 (*SWIFT*),

By Rev. GEORGE M. SEARLE.

This is continued from p. 112, that orbit at the end of three weeks still agreeing well; the corrections on Dec. 13 being —25s in α, and —5′ in δ, according to an observation then obtained by Mr. Wendell. Later computations seem to confirm the ellipticity already suggested.

Gr. M.T.	α	δ	log Δ	Br.
	h m s	° ′		
1889 Dec. 16.5	0 1 13	+20 22.8	9.9368	0.79
	7 50	20 56.4		
20.5	0 14 31	+21 29.6	9.9461	0.74
	0 21 18	+22 2.3		
1889 Dec. 24.5	28 9	22 33.3	9.9583	0.69
	35 7	23 4.1		
28.5	42 9	23 34.2	9.9704	0.65
	49 15	24 3.2		
1890 Jan. 1.5	0 56 24	24 31.2	9.9832	0.60
	1 3 35	24 58.2		
5.5	1 10 48	+25 24.2	9.9968	0.55

FILAR-MICROMETER OBSERVATIONS OF COMET *f* 1889 (*SWIFT*),

MADE WITH THE 12-INCH EQUATORIAL OF THE LICK OBSERVATORY.

By E. E. BARNARD.

1889 Mt. Hamilton M.T.	*	No. Comp.	☄ — * $\Delta\alpha$	☄ — * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
d h m s			m s	′ ″	h m s	° ′ ″		
Nov. 20 7 55 58	1	20 , 3	−1 28.73	−3 21.8	22 49 19.00	+12 45 51.7	9.152	0.577
21 6 52 28	2	10 , 8	−0 58.36	+1 12.6	22 51 27.93	+13 2 30.2	8.301	0.556
22 7 51 39	3	12 , 6	−0 48.73	+0 39.0	22 53 51.14	+13 20 43.4	9.152	0.562
25 7 38 11	4	10 , 6	+0 55.68	−8 34.1	23 0 58.83	+14 13 21.6	9.057	0.544
26 7 48 25	5	12 , 9	−0 10.52	−5 30.0	23 0 29.63	+14 31 1.9	9.161	0.544

Mean Places for 1889.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	22 50 45.90	+1.83	+12 18 51.2	+19.3	Schjellerup 9405
2	22 52 24.47	+1.82	+13 0 58.9	+18.7	$\frac{1}{3}$(W.B. 22ʰ 1051+2 Grant 6012)
3	22 51 38.04	+1.83	+13 19 15.6	+18.8	$\frac{1}{3}$(W.B. 22ʰ 1106+2 Grant 6031)
4	23 0 1.31	+1.84	+14 21 36.6	+19.1	$\frac{1}{3}$(W.B. 22ʰ 1235+2 Grant 6067)
5	23 1 8.32	+1.83	+14 36 12.9	+19.0	Compared with *α Pegasi*

Nov. 18–19. Rainy and foggy all night.

Nov. 20. Comet faint, about $\frac{3}{4}'$ diameter. Round, very gradually brighter in middle.

Nov. 21. Comet faint, about 13 magnitude, $\frac{3}{4}'$ diameter. Round, very gradually brighter in middle.

Nov. 22. Raining, with probably no more observations of the comet for some time.

Nov. 22. Comet faint, but better seen than before. It looks like a periodic comet.

The stars No. 1 = DM. 12°4912 and DM. 12°4925 seem to be affected by an error of about $1\frac{1}{2}'$ in δ. I measured the $\Delta\delta$, and found the preceding star 1′.3 S. of the following. These stars, brought up from SCHJELLERUP and WEISSE'S Bessel confirm the error in the DM., both being recorded there with the declination about $1\frac{1}{2}'$ too small.

Nov. 25, 26. Comet very faint from thick sky.

Star 5 — *α Pegasi*. $\Delta\alpha = 4^m\ 54^s.41 \quad \Delta\delta = -0'\ 16''.2$.

ELEMENTS OF COMET *e* 1889 (*DAVIDSON*).

By W. W. CAMPBELL.

From observations made at Windsor July 23, and at Washington August 19 and September 27, I have computed the following elliptic elements of this comet.

$$T = 1889 \text{ July } 19.2700 \text{ Gr. M.T.}$$

$$\left.\begin{aligned} \omega &= 315^\circ\ 51'\ 41''.1 \\ \Omega &= 286\ \ 10\ \ 30\ .1 \\ i &= 65\ \ 57\ \ 29\ .6 \end{aligned}\right\} 1889.0$$

$$\varphi = 81\ \ 7\ \ 17\ .7$$

$$\log a = 2.296008$$

$$\log q = 0.016829$$

$$\log \mu = 0.105995$$

Residuals (O—C),

$$\cos\beta'\,\Delta\lambda' = +0''.8, \quad \Delta\beta' = +1''.3.$$

NEW ASTRONOMICAL WORKS

Die Polhöhe der Königsberger Sternwarte, abgeleitet aus eigenen Beobachtungen, 1886, 1887, und verglichen mit Bessel'schen Beobachtungen, 1842–1844, von Dr. JOHANNES RAHTS.

In this memoir, which forms part of the 38th volume of the Königsberg Observations, Dr. RAHTS considers the question of a possible change in the latitude. He gives the results of his own observations of the zenith distance of *Polaris*, and compares them with the similar ones made by BESSEL and published in Nos. 481 and 482 of the *Astr. Nachrichten.*

From the recent series he deduces the value of the latitude for 1887.0, as 54° 42′ 50″.43 ± 0″.03; while BESSEL had obtained for 1843.0 the value 54° 42′ 50″.56 ± 0″.02.

Die Konstanten der Physischen Libration des Mondes, abgeleitet aus Schlüter's Königsberger Heliometer-Beobachtungen, von Dr. JULIUS FRANZ.

This treatise of 47 pages is also published as part of volume 38 from the Königsberg Observatory. SCHLÜTER'S observations, made during the years 1841–1843, were published in volume 28 of the same series; and WICHMANN had made some of the preliminary computations, which have been carefully tested by Dr. FRANZ, and a few errors corrected.

The author has fully presented the theory of the physical libration, and elaborately discussed the constants of the heliometer, and the series of observations. The crater "Mösting A" being, as is well-known, the point observed, its apparent position relative to the center of the lunar disk is given in the first place by the observations; and from these are deduced its selenocentric ecliptical coordinates, l and b. Computing the corresponding values l_0 and b_0, from assumed places of the selenographic coordinates of the crater λ and β, the differences $l_0 - l$ and $b_0 - b$ give equations of condition, for determining the desired constants of the physical libration.

An investigation of the influence of the lunar phase led only to a negative result; so that all consideration of this in the computations was demonstrably negligible.

The various equations of condition, the normal equations formed from them, and the values thence deduced, are given in full detail, the most important of the resulting values being:

for the mean inclination of the lunar equator to the ecliptic

$$I = 1^\circ\ 31'\ 22''.1 \pm 7''.3$$

for the position of the crater

$$\lambda = -5\ \ 10'\ 19''.0 \pm 7''.9, \quad \beta = -3^\circ\ 11'\ 24''.0 \pm 5''.5$$

and for the librations in longitude, node, and inclination, respectively

$$\begin{aligned} u &= 2'.2 \sin \odot - 0'.4 \sin(m-\pi) \\ \sin I\,w &= -1'.6 \sin(m-\pi) \\ w'' &= -1'.6 \cos(m-\pi) \end{aligned}$$

in which $\odot$ denotes the mean anomaly of the sun, and $(m-\pi)$ that of the moon.

The author arrives, moreover, at the conclusion that no inference regarding the secular change of the moon's mean motion can be derived from observations of the libration.

Annales de l'Observatoire Astronomique de Tokyo, Tome I. 1er fascicule.

This first publication of the results of the Imperial Observatory of Japan will receive, as such, a hearty welcome from the astronomical world. It contains a determination of the latitude of the Tokyo Observatory by Mr. H. WATANABE.

From 48 meridian zenith-distances of *Polaris*, observed with the Repsold circle, he obtained the value

$$35^\circ\ 39'\ 15''.05 \pm 0''.05$$

and by employing TALCOTT's method and 19 pairs of stars he found

$$35^\circ\ 39'\ 15''.40 \pm 0''.11.$$

Catalogue of Stars observed at the U. S. N. Observatory during the years 1845-1877, and prepared for publication by Prof. M. YARNALL. *3d Edition, revised and corrected, with renumbering of the stars, by* Prof. EDGAR FRISBY, *U. S. N. Washington, 1889.*

In this publication, issued as Appendix I to the Washington Observations of 1884, we have the well known Catalogue of YARNALL, revised, corrected, and rearranged. Before six years had elapsed since the issue of the first edition, it had become a work of continual reference, and indeed indispensable for practical astronomers; and, although its author added some 300 stars in the second edition, then published, he wisely refrained from changing the original notation — justly fearing the confusion which might otherwise arise. The completed volume of that edition reached him but an hour before his death, and after he had become unconscious; but he had personally superintended all its details, and the observations, reductions, and preparations for the press were almost entirely his own. None but those who knew the embarrassments and obstacles with which he successfully struggled, during the first half of the long period covered by his observations, can fully appreciate the greatness of his deserts.

The present, third, edition has been worthily edited ten years later still by his successor, Prof. FRISBY. All errors previously discovered have been corrected, and new ones detected by elaborate revision, and the numeration of the stars has been so modified as to include those added since the first edition. After the lapse of 16 years such change of notation is less likely to produce confusion than would have been the case at an earlier day; and since no essential change is to be expected in the future the present numeration will doubtless be a final one.

Prof. FRISBY has subjected the whole Catalogue to systematic revision, changing the nomenclature wherever this seemed desirable, re-examining all the stars not originally identified, and introducing references for such as he found in Catalogues previously existing. Inasmuch as YARNALL's original positions were chiefly derived from a combination of right-ascensions, determined with the transit-instrument, and declinations observed with the mural circle, it was almost inevitable that errors should sometimes arise from the combining of coordinates belonging to different stars. Such errors have been brought to light by careful identifications, now made possible by the publication of subsequent catalogues; or, in default of these, by direct reference to the sky. Indeed Prof. FRISBY states in his introduction, "it is believed that, with one or two exceptions, every star has been completely identified." He has recorded and explained in the notes the doubtful cases, and verified every position now given in the Catalogue.

The conscientiousness and patient care devoted to this edition by Prof. FRISBY, have been most fittingly bestowed upon a work whose author afforded an eminent illustration of the same qualities.

COMET *g* 1889.

A dispatch from Kiel announces the discovery of a faint comet by BORRELLY, at Marseilles. It was observed

Dec. 12.311 Gr. M.T. $\alpha = 18^h\ 7^m\ 0^s$ $\delta = +48^\circ\ 53'$. Daily motion, $+1^m\ 12^s$ in α, and 1° southward.

Prof. HOLDEN sends an observation by BARNARD.

Dec. 15.6425 Gr. M.T. $\alpha = 18^h\ 10^m\ 50^s.1$ $\delta = +15^\circ\ 30'\ 10''$

CORRIGENDA.

No. 206, p. 105, col. 1. l. 16
107, 2, 13 for $\cos^{3/2} 2Y$ put $\cos^{-3/2} 2Y$
109, 2, −5

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THE ORBIT OF SWIFT'S COMET 1880 V, DETERMINED BY GIBBS'S VECTOR METHOD.

BY W. BEEBE AND A. W. PHILLIPS.

(*Continued from page 117.*)

SUCCESSIVE CORRECTIONS.

Applying these corrections to the values of q_1, q_2, q_3, we compute the numbers in the second column of each of the above tables, and obtain the residuals

$$\alpha = 0.002497 \qquad \beta = -0.002163 \qquad \gamma = 0.001145$$

These combined with the old values of a_1, b_1, etc., G and L, give

$$C_1 = 0.0060059 \qquad C_2 = 0.0019159 \qquad C_3 = 0.0039142$$

The use of the old values of α', β', etc., renders necessary a slight change in the formulas for Δq. We write, therefore,

$$\Delta q_2 = \frac{C_2}{1 + L(Dq_2 + \frac{1}{2}C_2)}$$

$$\Delta q_1 = C_1 - L(Dq_2 + \tfrac{1}{2}C_2)\Delta q_2 \qquad \Delta q_3 = C_3 - L(Dq_2 + \tfrac{1}{2}C_2)\Delta q_2$$

where Dq_2 represents the preceding value of Δq_2. In general, at any stage of the work, Dq_2 will represent the sum of all the corrections of q_2 which have been made since the last computation of a_1, b_1, c_1, etc. The resulting corrections to be applied at the beginning of the third column of numbers in each of the above tables are

$$\Delta q_1 = -0.00360 \qquad \Delta q_2 = 0.00432 \qquad \Delta q_3 = 0.00632$$

In the third approximations we recompute all the quantities, and find

$\log a_1$ 9.147658 $\qquad \log a_2$ 9.063048 $\qquad \log a_3$ 9.039363
$\log b_1$ 9.001945 $\qquad \log b_2$ 8.922342 $\qquad \log b_3$ 8.902408
$\log c_1$ n9.064648 $\qquad \log c_2$ n8.980892 $\qquad \log c_3$ n8.953910

$\log G$ 6.52162 (mean of three values)

$$\alpha = -0.000148 \qquad \beta = 0.000123 \qquad \gamma = -0.000066$$

$$C_1 = 0.0023429 \qquad C_2 = 0.0015358 \qquad C_3 = 0.0013362$$

$\log H$ n7.55221 $\qquad \log L$ 1.12109

$$\Delta q_1 = 0.002325 \qquad \Delta q_2 = 0.001518 \qquad \Delta q_3\ 0.001318$$

These corrections furnish the basis for the calculations in the fourth column, which give the residuals

$$\alpha = 0.0000011 \qquad \beta = -0.0000018 \qquad \gamma = -0.0000005$$

and the new corrections

$$\Delta q_1 = -0.000094 \qquad \Delta q_2 = -0.000072 \qquad \Delta q_3 = -000061$$

These last residuals show that it is unnecessary to make a further approximation till the constants of the fundamental equation have been corrected.* The final values of q_1, q_2 and q_3, in this hypothesis, are

$$q_1 = 0.646051 \qquad q_2 = 0.649899 \qquad q_3 = 0.811217$$

TEST OF THE FIRST HYPOTHESIS.

We have now obtained the three heliocentric distances of the comet which satisfy the fundamental equation. This gives us three points lying in a plane with the sun, and in the lines of sight with the three observations respectively. Through these points we draw an ellipse and calculate the intervals of time required by the laws of elliptic motion for the passage of the comet between them. If these calculated intervals corrected for aberration are identical with the observed time-intervals we have the correct solution of the problem.

The time-intervals can be calculated from the length of the radii-vectores and the angles between them. If the fundamental equation be written in the form

$$n_1 R_1 - n_2 R_2 + n_3 R_3 = 0$$

it indicates that we may form a triangle whose sides are respectively parallel to the three heliocentric directions of the comet, and equal to $n_1 r_1$, $n_2 r_2$, $n_3 r_3$ (for brevity s_1, s_2, s_3). The angles between these directions may then be easily found. The time-intervals we shall, however, express in terms of the eccentric anomalies without computing the angles between the heliocentric directions.

---

* If we had used $\Delta q_2 = \dfrac{C_2}{1 + \frac{6}{5} L (Dq_2 + \frac{1}{2}C_2)}$ and in the expression for Δq_1 and Δq_3 in place of L, $\frac{6}{5} L$ the approximation would have been more rapid.

$$n_1 = A_1(1+R_1) = [\ 9.7013824] \qquad s_1 = n_1r_1 = [9.7350632]$$
$$n_2 = -(1-R_2) = [n9.9924188] \qquad s_2 = n_2r_2 = [0.0200242]$$
$$n_3 = A_3(1+R_3) = [\ 9.6994410] \qquad s_3 = n_3r_3 = [9.7323646]$$
$$S_4 = S_3 - S_1 \quad . \quad s_4^2 = S_4 . S_4 \qquad s = \tfrac{1}{2}(s_1+s_2+s_3) = 1.0652401$$
$$4A_2 = s_2^2s_4^2 - (S_2 . S_4)^2 \qquad A^2 = [8.3240421]$$
$$N = A_2R_1 + R_2 + A_3R_3 \qquad p = \frac{4A^2}{N(s_1+s_2+s_3)(-s_1+s_2+s_3)(s_1+s_2-s_3)} = [0.2430311]$$
$$P_1 = pn_1 - s_1 = 0.3365304 \qquad P_2 = pn_2 - s_2 = -0.6725020 \qquad P_3 = pn_3 - s_3 = 0.3359716$$
$$\text{check} \qquad P_1 + P_2 + P_3 = 0$$

Let I be a unit vector drawn from the sun towards the comet's perihelion, and $\bar{I}^1$ a unit vector drawn from the sun, at right angles to I, in the plane of the orbit, and on the side towards which anomalies increase.

Then
$$e\,I . S_4 = P_3 - P_1 = P_4 = -0.0005588 \qquad e\,I . S_2 = P_2 = -0.6725020$$
$$e\,I' . S_4 = -\frac{(S_4^2 P_2 + S_2 . S_4)P_4}{2A} = 0.1781342 \qquad e\,\bar{I}' . S_2 = -\frac{(\bar{S}_2 . \bar{S}_4)P_2 + s_2^2P_4}{2A} = 0.00633225$$
$$e^2 = \frac{(e\,\bar{I} . S_2)^2 + (e\,\bar{I}' . S_2)^2}{s_2^2} = \frac{(e\,I . \bar{S}_4)^2 + (eI' . S_4)^2}{s_4^2} = [9.6153772]\text{(average value)}$$
$$a = \frac{p}{1-e^2} = [0.4739904] \qquad b = \sqrt{ap} = [0.3585108]$$
$$e \sin E_1 = \frac{-e\,I' . \bar{S}_2 - eI' . S^4}{2bn_1} \qquad e \sin E_2 = e\,\bar{I}' . \bar{S}_2 \qquad e \sin E_3 = \frac{-e\,I' . \bar{S}_2 + e\,I' . \bar{S}_4}{2bn_3}$$

$\log \sin E_1 = n9.0973068$ $\qquad E_1 = -7°\ 11'\ 14''.47$
$\log \sin E_2 = n7.6429394$ $\qquad E_2 = -0°\ 15'\ \ 6''.50$
$\log \sin E_3 = \ \ 9.0683591$ $\qquad E_3 = \ \ 6°\ 43'\ 18''.08$

$\tau_1 = a^{3/2}(E_3 - E_2) + ea^{3/2}\sin E_2 - ea^{3/2}\sin E_3 = \quad 0.2247191$
$\delta\tau_1(\text{aberr. corr.}) = 0.005762\ \kappa(\rho_3 - \rho_2) \quad = -0.0000007$
$\log\tau_1(\text{corrected for aberration}) \quad = \quad 9.3516375$
$\log\tau_1(\text{observed}) \quad = \quad 9.3515856$
$\Delta \log \tau_1 \quad (O-C) \quad -0.0000519$

$\tau_3 = a^{3/2}(E_2 - E_1) + ea^{3/2}\sin E_1 - ea^{3/2}\sin E_2 = \quad 0.2236987$
$\delta\tau_3(\text{aberr. corr.}) = 0.005762\ \kappa(\rho_2 - \rho_1) \quad = -0.0000027$
$\log\tau_3(\text{corrected for aberration}) \quad = \quad 9.3496571$
$\log\tau_3(\text{observed}) \quad = \quad 9.3496105$
$\Delta \log \tau_3 \quad (O-C) \quad -0.0000466$

Correction of the Fundamental Equation.

The logarithms of τ_1 and τ_3 corrected for aberration exceed those of the corresponding observed values by 0.0000519 for the first, and 0.0000466 for the second. If we solve the fundamental equation, using time-intervals shortened by these amounts, the intervals calculated from this second solution must agree almost exactly with the observed intervals. The following equations give the corrections for the constants which depend on the time-intervals.

$$\Delta \log (\tau_1\tau_3) = \Delta \log \tau_1 + \Delta \log \tau_3 \quad = -0.0000985$$
$$\Delta \log \frac{\tau_1}{\tau_3} = \Delta \log \tau_1 - \Delta \log \tau_3 \quad = -0.0000053$$
$$\Delta \log A_1 = A_3\,\Delta \log \frac{\tau_1}{\tau_3} \quad = -0.0000027$$
$$\Delta \log A_3 = -A_1\,\Delta \log \frac{\tau_1}{\tau_3} \quad = \quad 0.0000026$$
$$\Delta \log B_1 = \Delta \log (\tau_1\tau_3) - \frac{\tau_1^2 + \tau_3^2}{12B_1}\Delta \log \frac{\tau_1}{\tau_3} = -0.0000878$$
$$\Delta \log B_2 = \Delta \log (\tau_1\tau_3) + \frac{\tau_1^2 - \tau_3^2}{12B_2}\Delta \log \frac{\tau_1}{\tau_3} = -0.0000985$$
$$\Delta \log B_3 = \Delta \log (\tau_1\tau_3) + \frac{\tau_1^2 + \tau_3^2}{12B_3}\Delta \log \frac{\tau_1}{\tau_3} = -0.0001090$$

Applying these corrections to the values of the constants used in the first hypothesis, we have for the

Second Hypothesis.

$\log A_1 = 9.6999538 \qquad \log A_3 = 9.6979840$

$\log B_1 = 7.6179587 \quad \log B_2 = 8.3208882 \quad \log B_3 = 7.6258382$

We now proceed with the second hypothesis in precisely the same manner as with the first, except that we content ourselves with the values of α^1, β^1, γ^1, a_1, b_1, c_1, G and L last computed, and calculate Δq_1, Δq_2, Δq_3 by the second method employed in the last hypothesis.

$$q_1 = \rho_1 + .4864199 \qquad \alpha_1 = [\ 9.5700863](1+R_1)(q_1 + \ .6374005)$$
$$r_1^2 = q_1^2 + .7504001 \qquad \beta_1 = [n9.3739148](1+R_1)(q_1 - 1.5375496)$$
$$R_1 = [7.6179587]r_2^{-3} \qquad \gamma_1 = [\ 9.3782729](1+R_1)(q_1 - \ .0348441)$$

$\Delta q_1 = \Delta\rho_1$		0.002180	—0.0000225	—0.0000017
ρ_1	0.159631	.1618110	.1617885	.1617868
q_1	.646051	.6482309	.6482084	.6482067
r_1^2	1.167782	1.1706031	1.1705742	1.1705720
R_1	.003288	.0032760	.0032761	.00327612
Components of S_1 α_1	.4785104	.4793171	.4793090	.17930843
β_1	.2115735	.2110536	.2110589	.21105932
γ_1	.1465166	.1470371	.1470320	.11703160
$\log G_1$	6.52162 From first hypothesis			
$\log L$	1.12109			
C_1	.002236	— .0000221	— .00000163	
Δq_1	.002180	— .0000225	— .0000017	
Components of $\bar{S}$ α	—0.0000055	0.0000037	—0.0000005	—0.0000000,6
β	—0.0000019	—0.0000030	0.0000001	0.0000000,2
γ	—0.0000019	0.0000018	—0.0000005	—0.0000001,0

$q_2 = \rho_2 + .5170330$
$r_2^2 = q_2^2 + .7131934$
$R_2 = [8.3208882]r_2^{-3}$

$\alpha_2 = [n9.8444950](1-R_2)(q_2 + .4667338)$
$\beta_2 = [\ 9.3750306](1-R_2)(q_2 - 3.2730050)$
$\gamma_2 = [n9.8290614](1-R_2)(q_2 - .0966450)$

$\Delta q_2 = \Delta\rho_2$		0.001788	—0.0000082	—0.0000018
ρ_2	0.132866	.1346540	.1346458	.1346440
q_2	.649899	.6516870	.6516788	.6516770
r_2^2	1.135562	1.1378894	1.1378787	1.1378763
R_2	.017301	.0172479	.0172481	.01724818
Components of $\bar{S}_2$ α_2	— .7670541	— .7683238	— .7683179	— .76831662
β_2	— .6113177	— .6109340	— .6109358	— .61093613
γ_2	— .3667808	— .3679860	— .3678050	— .36797929
C_2	.0018444	— .00000857	— .00000186	
Δq_2	.001788	— .0000082	— .0000018	

$q_3 = \rho_3 + 0.6850433$
$r_3^2 = q_3^2 + .5056433$
$R_3 = [7.6258382]r_3^{-3}$

$\alpha_3 = [9.4455276](1+R_3)(q_3 + .2196827)$
$\beta_3 = [8.9139481](1+R_3)(q_3 + 4.0458360)$
$\gamma_3 = [9.6078527](1+R_3)(q_3 - .2696800)$

$\Delta q_3 = \Delta\rho_3$		0.001698	—0.0000059	—0.0000010
ρ_3	0.126174	.1278720	.1278661	.1278651
q_3	.811217	.8129153	.8129094	.8129084
r_3^2	1.163717	1.1664746	1.1664651	1.1664634
R_3	.003366	.0033537	.00335373	.00335371
Components of $\bar{S}_3$ α_3	.2885382	.2890100	.2890084	.28900813
β_3	.3997422	.3998774	.3998769	.39987683
γ_3	.2202623	.2209504	.2209480	.22091709
C_3	.004754	— .0000055	— .0000009	
Δq_3	.001698	— .0000059	— .0000010	

TEST OF THE SECOND HYPOTHESIS.

$\log n_1$	9.7013743
$\log n_2$	9.9924444
$\log n_3$	9.6994381
$\log s_1$	9.7355732
$\log s_2$	0.0204914
$\log s_3$	9.7328736
s	1.0664394
$\log S_2.S_1$	7.5629919
$\log s_4^2$	8.8883471
$\log A^2$	8.3272015
$\log p$	0.2462279
P_1	.3423761
P_2	— .6841805
P_3	.3418011
Check $P_1 + P_2 + P_3$	— .0000003

Corrected values of P_1	0.3423762	
P_2	0.6841801	
P_3	0.3418012	
$e\,L.S_1$	—0.0005720	
$e\,L.S_2$	0.6841804	
$e\,L'.S_1$	0.1814972	
$e\,L'.S_2$	0.0061245	
$\log e^2$	9.6293969	
$\log a$	0.4873065	
E_1	—7° 4′ 6″.85	
E_2	—0° 14′ 47″.88	
E_3	6° 36′ 45″.34	
$\log \tau_1$	9.3515867	Corrected for aberration
$\log \tau_3$	9.3496113	" " "
$\Delta \log \tau_1$	—0.0000011	(O—C)
$\Delta \log \tau_3$	—0.0000008	(O—C)

The agreement between the observed and calculated values of the time-intervals is so close that it is unnecessary to make a third hypothesis.

TIME OF PERIHELION AND POSITION OF ORBIT.

The time of perihelion passage may be found from each of the three positions by the following formula:

$$t - T = a^{3/2} k^{-1} (E - e \sin E)$$

$t_1 - T = -13.470522$	$t_1 =$ Oct. 25.313242	$T_1 \doteq$ Nov. 7.782832
$t_2 - T = -\ 0.467778$	$t_2 =$ Nov. 7.315808	$T_2 =$ " 7.782810
$t_3 - T = 12.594117$	$t_3 =$ " 20.377642	$T_3 =$ " 7.782789

$T_0 =$ Nov. 7.782810 (mean of three values)

The vectors $\bar{I}$ and $\bar{I}'$ may be found from

$$\bar{I} = \frac{1}{2Ae} \left[-(e\bar{I}' . \bar{S}_4)\bar{S}_2 + (e\bar{I}' . \bar{S}_2)\bar{S}_4 \right]$$

$$\bar{I}' = \frac{1}{2Ae} \left[-(e\bar{I} . \bar{S}_4)\bar{S}_2 - (e\bar{I} . \bar{S}_2)\bar{S}_4 \right]$$

Call the unit vector, drawn from the sun above and perpendicular to the plane of the ecliptic, $\bar{M}$. The obliquity of the ecliptic (1880.0) = 23° 27′ 17″.1. We shall have for the components of $\bar{I}$, $\bar{I}'$ and $\bar{M}$,

Components of $\bar{I}$	$\log i$ 9.8612565	$\log j$ 9.7702621	$\log k$ 9.5484412
" $\bar{I}'$	$\log i$ n9.8338123	$\log j$ 9.8330566	$\log k$ 9.4263840
" $\bar{M}$	i 0	$\log j$ n9.5999100	$\log k$ 9.9625467

$\log (\bar{M} . \bar{I})$ 8.9533479 $\log (\bar{M} . \bar{I}')$ n8.4171560

The inclination of the orbit, the distance from perihelion to node, and the longitude of the node, may be found from the following formula:

$$\sin^2 i = (\bar{M} . \bar{I})^2 + (\bar{M} . \bar{I}')^2 = [7.9419846] \qquad \cos(\pi - \Omega) = \frac{\bar{M} . \bar{I}'}{\sin i} = [n9.4461637]$$

$$\cos \Omega = \frac{(\bar{i} . \bar{I}\ \bar{k} . \bar{I}') - (\bar{i} . \bar{I}'\ \bar{k} . \bar{I})}{\sin i} = [9.6550662].$$

The elements thus computed are as follows. Below are given elements which we have computed from eight observations ranging between October 25, 1880, and January 7, 1881. Both are referred to the ecliptic and mean equinox of 1880.0.

EIGHT OBSERVATIONS.

$i =$ 5° 23′ 3″.8
$\pi - \Omega =$ 106 13 4 .1
$\Omega =$ 296 42 55 .1
$\log e =$ 9.8163726
$\log a =$ 0.4905937
$T =$ 1880 Nov. 7.786610
Periodic Time = 1988.33 days

THREE OBSERVATIONS.

$i =$ 5° 22′ 2″.03
$\pi - \Omega =$ 106 13 19 .17
$\Omega =$ 296 52 2 .09
$\log e =$ 9.8146985
$\log a =$ 0.4873065
$T =$ 1880 Nov. 7.782810
Periodic Time = 1965.88 days

EPHEMERIS.

The ephemeris is computed from the following formula.

$$\bar{R} = -ea\,\bar{I} + a \cos E\,\bar{I} + b \sin E\,\bar{I}'$$

The values of E computed from the mean value of T are

$E_1 = -7° 4' 6''.81 \quad E_2 = 0° 14' 47''.88 \quad E_3 = 6° 36' 45''.30$

Components of $\bar{R}_1$ R_2 $\bar{R}_3$

$x_1 = 0.9533240$	$x_2 = 0.7818013$	$x_3 = 0.5773943$
$y_1 = 0.4197893$	$y_2 = 0.6216590$	$y_3 = 0.7988920$
$z_1 = 0.2924401$	$z_2 = 0.3744379$	$z_3 = 0.4414194$

Combining these values with the heliocentric coordinates of the Observatory, we find for the right-ascension and declination at the times of observation.

$\alpha_1 = 327° 31' 18''.1$	$\alpha_2 = 341° 15' 36''.2$	$\alpha_3 = 16° 23' 7''.9$
$\delta_1 = 28\ 28\ 32.4$	$\delta_2 = 42\ 25\ 30.2$	$\delta_3 = 54\ 20\ 56.6$

O—C			
$\Delta\alpha$	—0″. 9	—0″. 7	1″. 5
$\cos\alpha\,\Delta\delta$	—0.92	—0.47	0.67

NOTE FROM MR. MOTODA.

Though there have been written many papers about the well known differential equation

$$\frac{d^2x}{dt^2} + (m^2 - 2\beta \cos t)x = 0$$

of the theory of perturbation, the method of solution which I now communicate to you seems not to have been considered in any of them.

My method consists in expanding x in powers of β by

Taylor's Theorem, and in determining the coefficients of different powers of β by means of the differential equation. For this purpose we write

$$(1)\qquad x = x_0 + \beta x_1 + \frac{\beta^2}{2} x_2 + \ldots$$

where $x_0, x_1 \ldots$ are functions of t and m. Put this in the differential equation, and equate the coefficients of β^i to zero, then we obtain

$$\frac{d^2x_0}{dt^2} + m^2x_0 - 2i\, x_{i-1}\, \cos t = 0.$$

This gives x_i in terms of x_{i-1}. This may be transformed into the integral form:

$$x_i = \frac{2i}{m}\left[\sin mt \int \cos t \cos mt\, x_{i-1} dt - \cos mt \int \cos t \sin mt\, x_{i-1} dt\right]$$

$$(2)\qquad + \text{complementary solution.}$$

Where $i = 0$, $\frac{d^2x_0}{dt^2} + m^2x_0 = 0$ which gives

$$x_0 = A\cos(mt+B)$$

where A and B are constants. As x_0 becomes known, $x_1\, x_2 \ldots$ can be successively calculated by the formula (2). I found

$$x_1 = A\cos(mt+B) + \frac{A}{m}\Big\{ \sin t \sin(mt+B)$$

Tokio, Japan, 1889 *October* 9.

$$+ \frac{\sin[(3m+1)t+B]}{2(2m+1)} + \frac{\cos[(3m+1)t+B]}{2(2m-1)} \Big\}$$

$x_2 =$ &c., &c.

It is easily seen that $x_1, x_2 \ldots$ etc. are integral functions of sine and cosine of mt.

We have supposed that m is different from zero, unless the above fails. But when $m =$ zero the equation which determine x_0 becomes

$$\frac{d^2x_0}{dt^2} = 0 \quad \text{which gives} \quad x_0 = At + B$$

where A and B are constants. Hence in this case it is only necessary to put the just found value of x_0, instead of the former value, in (2) (remembering $m = 0$), and proceed as before. Also, x_i is an integral function of sine and cosine of t, as well as of t itself.

The method seems to be applicable to the more general case where the differential equation is of the form

$$\frac{d^2x}{dt^2} + \left\{ m^2 - 2\beta\left(\Sigma_i (A_i \sin N_i t + B_i \cos N_i t)\right) \right\} x = 0$$

T. MOTODA.

SUN-SPOTS, 1887-1889.

By WILLIAM DAWSON.

The following table is a continuation of the series in the *Astronomical Journal*, 1888 May 17, No. 172. The telescope has 4.6 inches aperture and 70 in. focus. Full aperture used. A power of 100 was employed where no other is marked. Prostrating illness prevented much observation during 1887, and absence in summer of 1888.

Date	Hour	Wt.	Gp.	Sp'ts	Notes
1887 Jan. 2	2	2	2	3	1 s N of center
22		2	1	1	power 30
Aug. 6	5	4	1	40	10 s prominent
28	9	5	1	2	s little at W edge
Sept. 5	8	3	0	0	
13	8½	3	1	1	s in SE quadrant
16	8½	3	1	16	one s l
20	9	5	1	40	2 s l; 4 prominent
Oct. 31	9½	3	1	3	s little: near W side
Nov. 8	4	2	1	2	p 50; s E of center
1888 Feb. 20		4	1	40	7 s prominent
28	3	1	1	5	p 50; g near W edge
Mar. 5	3	2	0	0	p 50
8	9	3	0	0	No faculae
12	10	4	2	13	2 s l 9′ from E edge
14	9	2	1	10	
15	12	3	1	8	a l s divided into 3 s
Sept. 6	9	2	1	1	s 1′ from W edge
7	8	5	2	10	new g near W edge
8	8	4	1	12	s all l
11	8⅓	4	0	0	no faculae
14	7½	5	0	0	hardly any faculae
15	8	4	0	0	" "
18	8⅓	3	0	0	" "
1888 Sept. 19	3⅓	4	0	0	
22	9	5	0	0	
23	8½	5	0	0	
24	8⅓	3	0	0	
26	8	2	1	8	p 50; air very poor
Oct. 1	4	3	1	4	p 50
2	8	4	1	8	p 50
5		3	0	0	p 50
8			0	0	p 50
9			0	0	p 50
11	8	3	0	0	p 50; hardly any fac.
15	8	4	0	0	no faculae
18	9½	4	0	0	"
21	9⅓	4	0	0	"
23	9	3	0	0	"
28	3½	3	0	0	
29	9¼	3	0	0	
Nov. 3	9⅓	1	0	0	air very tremulous
4	8¼	3	0	0	faculae E; p 50
5	9	3	0	0	p 50
6	9	3	0	0	p 50
12	7½	3	0	0	p 50
13	10½	3	0	0	

Spiceland, Ind., 1889 *November* 14.

CONTRIBUTIONS TO THE KNOWLEDGE OF THE INEQUALITIES IN THE PERIODS OF THE VARIABLE STARS,

By S. C. CHANDLER.

III.

7560. *R Vulpeculae.*

Schönfeld, from a discussion of the observations from 1859 to 1874, found that a uniform period left systematic deviations outstanding, which exceeded seven or eight fold the uncertainty of the single maxima; but that a quadratic term corresponding to a shortening of $0^d.12$ from epoch to epoch, brought them within the range of the probable errors. In this case, as in all others where such terms are resorted to as temporary expedients, the divergence from observation soon began, and rapidly widened, as will be seen in the column of O—C marked "Sch.," below.

Column *A* contains the deviations from the elements of my catalogue, namely:

$$(A)\ \left\{\begin{array}{l}\text{Max. 1865 Sept. 20.0}\\ \text{Min. 1865 July 19.0}\end{array}\right\} + 136.9E + 20.0\sin(4^\circ E + 90^\circ)$$

which were derived from a part of the data only. A revision gives the values

$$(B)\ \left\{\begin{array}{l}\text{Max. 1865 Sep. 18.5}\\ \text{Min. 1865 July 14.3}\end{array}\right\} + 136.93E + 22.0\sin(4^\circ.8 + 72^\circ)$$

corresponding to the last column of residuals, and to these calculated times:

Epoch	Maxima	Minima
64	1889 Sept. 23	1889 July 19
65	1890 Feb. 9	Dec. 4
66	June 27	1890 Apr. 22
67	Nov. 13	Sept. 8
68	1891 Mar. 31	1891 Jan. 24
69	Aug. 17	June 11
70	1892 Jan. 2	Oct. 27

In the table of observations, the only abbreviations not already used are Pi for Piazzi, and Sb for Schwab.

		O—C			
E	Observed Maxima	Sch.	*A*	*B*	Obs.
—155	1807 Aug. 23		+ 9.9	— 9.2	Pi
147	1810 Aug. 10		—13.2	—15.1	"
17	1859 May 6	+ 8.3	— 9.2	+ 4.3	Wn
16	Sept. 12	— 2.1	—18.4	— 5.8	"
10	1861 Dec. 30	+ 3.5	— 6.3	+ 1.9	Kn
8	1862 Oct. 5.0	+ 5.2	— 2.8	+ 3.7	"
5	1863 Nov. 19.4	+ 0.9	— 4.9	— 0.7	"
"	Nov. 18.9	+ 0.1	— 5.4	— 1.2	Bx
3	1864 Aug. 16.3	— 4.2	— 8.6	— 6.0	Kn
2	1865 Jan. 7.3	+ 2.0	— 1.7	+ 0.2	"
— 1	May 25.5	+ 2.6	— 0.6	+ 0.6	"
0	Oct. 5.5	— 2.0	— 1.5	— 3.9	"
+ 1	1866 Mar. 6	+ 12.1	+10.1	+ 9.9	"
2	July 6.0	— 3.3	— 4.7	— 5.2	Sd
"	July 7.0	— 2.3	— 3.7	— 4.2	Kn
22	1873 Dec. 17	— 3.5	— 2.5	— 1.9	Sd
23	1874 May 6	+ 1.7	+ 2.0	+ 3.0	"
+ 24	Sept. 13	— 3.0	— 3.5	+ 2.0	"
+ 25	1875 Jan. 29	+ 0.5	— 1.0	+ 0.8	"
35	1878 Oct. 19	+ 10.5	+ 0.8	+ 4.9	Sb
49	1884 Jan. 12	+ 77.1	— 0.9	— 2.5	Ch
51	Oct. 15	+ 91.1	+ 1.4	— 1.8	Kn
+ 53	1885 July 20	+106.5	+ 4.3	— 0.5	"
	Minima				
— 10	1861 Oct. 26.3	+ 2.8	— 8.0	+ 3.4	Kn
5	1863 Sept. 18.3	+ 2.8	— 4.0	+ 3.3	"
3	1864 June 19.5	+ 2.0	— 3.4	+ 2.3	"
— 2	Nov. 4.0	+ 1.7	— 3.0	+ 2.1	"
0	1865 Aug. 6.3	+ 1.8	— 1.7	— 2.1	"
+ 1	Dec. 14.3	— 5.6	— 8.6	— 5.3	"
4	1867 Jan. 31	— 4.5	— 5.8	— 4.0	"
24	1874 July 12	— 2.0	— 3.5	+ 1.2	Sd
49	1883 Nov. 9	+ 77.1	— 1.9	— 0.3	Ch
51	1884 Aug. 10	+ 89.1	— 1.6	— 1.6	Kn
+ 56	1886 July 5	+127.5	+ 4.0	— 2.8	"

SOME OBSERVED MAXIMA OF LONG-PERIOD VARIABLES,

By PAUL S. YENDELL.

S Delphini.

Twenty-one observations of this variable, from June 20 to September 27, show a maximum to have been passed July 24. When first observed it was of about the tenth magnitude, rising at maximum to $9^M.5$; at the last observation, September 27, it had again fallen to 10^M.

R Camelopardalis.

Ten observations were secured, from July 6 to September 18, showing a well-marked maximum on August 9; at the first observation the star's light is estimated to have been 8^M; it rose quite steadily to $7^M.5$, declining rather more quickly than it had increased. Its light at the last observation was about $8^M.3$.

R Bootis.

But seven observations were obtained of this star, between August 16 and September 19; its brightness at the first observation was about 8^M, this being the only one obtained before the maximum. On August 20 the star had risen to $7^M.8$, the rise, though slight, being well marked. The remaining observations indicate a pretty regular decrease to $8^M.5$ on September 19. This cannot fairly be called a well-determined maximum, yet enough observations were secured to place the date of that phase *not later* than Aug. 20.

S Ursae Majoris.

Thirteen observations of *S Ursae Majoris* indicate that a not very distinctly marked maximum, at $7^M.2$, occurred September 5. The fluctuations of the two preceding maxima seem not to have been repeated, but the unsteadiness of the star's changes render the precise point of the maximum phase a little uncertain. The final decline was very sharp, a fall of a full half-magnitude taking place between September 27 and October 10, at which time the star was last observed, and when its light is estimated at $8^M.7$.

Dorchester, Mass., 1889 *October* 28.

S Herculis.

The first observation of this star was made June 4, when it was near the ninth magnitude by eye-estimation. Its rise was very slow, reaching $8^M.2$ only on August 15, between which date and that of the maximum which was passed on August 25, the star increased to the $7^M.5$. Its decline was more steady and rapid, and it had reached $8^M.5$ on September 19, when the last observation was made. The observations number in all eighteen.

PHOTOMETRIC OBSERVATIONS OF ASTEROIDS.

By HENRY M. PARKHURST.

The observations, commenced in April 1887, a report of which for that year is published in the *Annals of the Harvard College Observatory*, Vol. XVIII, No. 3, have been continued during the two succeeding years. During the first year, eighteen asteroids were observed. Since that time eighteen additional asteroids have been observed, and many have been observed in different seasons. I have not yet found conclusive evidence of intrinsic variability in their light. All the extended series show their reliability as photometric standards, upon applying the corrections for distance and for phase. Whatever other variations there may be, are so small and of so short a period as to become inappreciable in a series of observations.

The phase-correction arising from defect of illuminated surface, is always small; but there is an additional phase-correction, the cause of which is yet unknown, which cannot be neglected. It seems to be proportional to the angle P, at the asteroid, between the sun and the earth; and does not vary materially from that. But the factor p, of the correction pP, varies greatly in different asteroids. The results obtained are given in the following table:

No.	G	p	ΔP	No.	G	p	ΔP	No.	G	p	ΔP	No.	G	p	ΔP
1	3.71	0.043	34	12	7.66	0.020	21	29	5.80	0.033	11	105	8.09	0.100	10
2	4.50	.033	12	16	5.83	.046	30	30	7.88	.025	32	110	8.91	–	3
3	5.77	.030	35	18	6.59	.033	30	37	6.70	.09	3	111	7.15	.12	2
4	3.49	.018	25	19	7.23	.10	3	40	7.66	.020	28	122	8.13	.04	3
5	7.06	.025	21	20	6.40	.052	29	42	8.38	–	0	127	9.27	.020	11
6	6.33	.023	27	23	6.65	.08	7	43	8.27	.020	6	187	9.51	–	0
7	6.30	.016	39	25	8.11	.025	12	44	7.16	.025	22	192	7.37	.020	23
8	6.71	.028	40	27	6.88	.067	20	51	7.39	.06	5	200	8.74	–	0
11	6.92	0.022	13	28	7.40	0.04	5	75	9.36	0.030	20	261	10.28	0.017	15

The first column contains the number of the asteroid. The second column contains the standard brightness, the distances from the sun and earth being reduced to unity, and the phase-corrections deducted. The ratio of magnitude is 2.512, and the standard that of the Harvard Photometry. The additional phase-correction is $+pP$, P being reckoned in degrees: and sometimes exceeds a whole magnitude. ΔP, contained in the fourth column, is the sum of the observed variation in P, for the three years. The mean value of p, giving weights proportional to ΔP, is 0.031; nearly coincident with my former determination, 0.033.

25 *Chambers St., New York City*, 1889 *Dec.* 1.

COMET OBSERVATIONS.

Professor KRUEGER has kindly telegraphed an observation of the Comet *g* 1889, made by him at Kiel.

Dec. 15.2166 Greenwich M.T. $\alpha = 18^h\ 10^m\ 22^s.1$ $\delta = +45°\ 51'\ 44''$

From Prof. FRISBY at Washington we have a single observation of Comet *d*:

Nov. $23^d\ 9^h\ 36^m\ 11^s.6$ Washington M.T. $\alpha = 23^h\ 53^m\ 59^s.82$ $\delta = +0°\ 32'\ 32''.1$

ELLIPTIC ELEMENTS OF COMET *f* 1889, WITH EPHEMERIS.

BY REV. GEORGE M. SEARLE.

I have computed by the method given in No. 206 of the *Astronomical Journal*, the following elliptic elements of Comet *f* 1889 from three observations on Nov. 18, Nov. 26, and Dec. 13, made by Mr. WENDELL of Harvard College Observatory, and kindly furnished by Prof. PICKERING.

$$T = \text{Nov. } 29.8212 \text{ Gr. M.T.}$$

$$\left.\begin{aligned} \Omega &= 330^\circ\ 24'\ 58'' \\ \omega &= \ \ 70\ \ \ \ 1\ \ \ \ 5 \\ i &= \ \ 10\ \ \ 15\ \ \ \ 3 \end{aligned}\right\} 1889.0$$

$$\log q = 0.131746$$
$$\varphi = 43^\circ\ 3'\ 18''$$
$$\log a = 0.630275$$
$$\text{Period} = 3221 \text{ days.}$$

Middle place (O—C).

$$\Delta\lambda = -5'' \qquad \Delta\beta = 0''$$

The orbit is as yet somewhat uncertain, owing to the peculiar conditions of the problem.

The following ephemeris for Greenwich mean midnight and mean equinox 1890.0, results from these elements.

Gr. M.T.		App. α			App. δ		log Δ	Br.
		h	m	s	°	′		
1889 Dec.	24	0	26	56	+22	24.5	9.9059	0.66
	26		33	48	22	55.1		
	28		40	44	23	25.2	.9183	.61
	30		47	43	23	54.0		
1890 Jan.	1	0	54	46	24	21.9	.9314	.56
	3	1	1	52	24	48.8		
	5		9	0	25	14.7	.9451	.52
	7		16	10	25	39.6		
	9		23	22	26	3.5	.9595	.47
	11		30	35	26	26.3		
	13		37	49	26	48.0	.9743	.43
	15		45	4	27	8.6		
	17		52	19	27	28.2	9.9897	.39
	19	1	59	33	27	46.7		
	21	2	6	47	28	4.0	0.0055	.36
	23		14	0	28	20.2		
	25	2	21	12	+28	35.4	0.0216	0.32

EPHEMERIS OF VARIABLES OF THE *ALGOL*-TYPE.

Approximate Greenwich M.T., 1890.

	January			January			January			January			January	
	d	h		d	h		d	h		d	h		d	h
Y Cygni	1	11	*R* Can. Maj.	7	13	λ Tauri	15	8	*R* Can. Maj.	22	7	*U* Cephei	27	8
U Cephei	2	9	*R* Can. Maj.	8	16	*R* Can. Maj.	15	11	*U* Cephei	22	8	*S* Cancri	27	18
Algol	3	10	*S* Cancri	8	19	*Y* Cygni	16	11	*Y* Cygni	22	11	*Y* Cygni	28	11
λ Tauri	3	11	*R* Can. Maj.	9	19	*R* Can..Maj.	16	15	λ Tauri	23	5	*U* Cephei	29	19
Y Cygni	4	11	*U* Cephei	9	21	*U* Cephei	17	8	*R* Can. Maj.	23	10	*R* Can. Maj.	30	6
U Coronae	4	21	*Y* Cygni	10	11	*R* Can. Maj.	17	18	Algol	23	11	*R* Can. Maj.	31	9
U Cephei	4	21	λ Tauri	11	9	Algol	17	18	*R* Can. Maj.	24	13	*Y* Cygni	31	10
R Can. Maj.	5	6	*U* Coronae	11	18	*S* Cancri	18	6	*U* Cephei	24	20			
δ Librae	5	21	*U* Cephei	12	9	*U* Coronae	18	16	*Y* Cygni	25	11		February	
Algol	6	7	δ Librae	12	20	λ Tauri	19	6	*U* Coronae	25	14	*U* Cephei	1	7
R Can. Maj.	6	9	*R* Can. Maj.	13	5	*Y* Cygni	19	11	*R* Can. Maj.	25	17	*R* Can. Maj.	1	13
U Cephei	7	9	*Y* Cygni	13	11	δ Librae	19	20	Algol	26	8	*R* Can. Maj.	2	16
λ Tauri	7	10	*R* Can. Maj.	14	8	*U* Cephei	19	20	δ Librae	26	19	δ Librae	2	19
Y Cygni	7	11	*U* Cephei	14	20	Algol	20	15	λ Tauri	27	4	*Y* Cygni	3	10

CORRIGENDA.

No. 206, p. 109, col. 2. line 17, for $y_0 = \dfrac{X_1}{Q}\rho_0$ put $y_0 = \dfrac{X_1}{Q} - \rho^0$

No. 207, p. 115, lines 17-19, last term of second member, for $P'\alpha'$, $P'\beta'$, $P'\gamma'$ put $P'\alpha_1$, $P'\beta_1$, $P'\gamma_1$

" p. 119, Nov. 26, comet's apparent α, for $23^h\ 0^m\ 29^s.63$ put $23^h\ 3^m\ 29^s.63$.

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NOTES ON FUNDAMENTAL RIGHT-ASCENSIONS.

BY HENRY FARQUHAR. OFFICE OF UNITED STATES COAST SURVEY.

[Communicated by permission of the Superintendent.]

The right-ascensions of the following list of stars, as obtained from the *Berliner Jahrbuch*, gave a succession of residuals of the same sign through an extended series of longitude-observations carefully made in 1888, and have just been examined by me under direction of Mr. C. A. SCHOTT, Chief of the Computing Division in this office.

The systematic corrections applied were derived from Publication XIV of the *Astronomische Gesellschaft* for the catalogues used therein, and from Appendix 3, *Washington Observations* for 1870, with the addition of

$$0^s.0008\ (1868-T)$$

for those used by Prof. NEWCOMB. As Prof. BOSS, in nos. 196 and 200 of the *Astronomical Journal*, uses a very different equation, the source of his error should be pointed out. He confuses Dr. AUWERS's reduction of Bradley with the *A.G.* standard for 1755, which differs from it by the correction applied to the Greenwich first seven-year catalogue. The hypothesis of Dr. AUWERS, that his reduction of Bradley has a systematic error in every respect identical with that of AIRY in 1860, appears at first view a somewhat fantastic one, but this hypothesis is nevertheless the basis of his proper-motions, in both coordinates. The difference between AUWERS and NEWCOMB for 1755 is therefore $+0^s.056$, the correction applied to Dr. AUWERS's preliminary reduction, diminished by $-0^s.010$ (NEWCOMB's correction to that preliminary reduction), and increased by $+0^s.025$, the mean value, between $+35°$ and $-15°$ declination, of the correction applied by Dr. AUWERS (see page 10 of Publ. XIV) to Greenwich 1860; total $+0^s.091$. A comparison of NEWCOMB's places for 1875, calculated in Appendix 3, with those of the *A.G.* in Publications XIV and XVII, gives this difference for the mean of 31 stars, *α Canis Majoris* being unavoidably rejected:

$$AG-N = -0^s.0058 \pm 0^s.0006$$
$$-(0^s.00077 \pm 0^s.00001)(T-1875)$$

A periodic correction to the proper-motions of

$$+0^s.00002 \cos\alpha + 0^s.00014 \sin\alpha,$$

is not admitted, being doubtless accidental. Separation of the stars into groups shows for

8	stars of	mean decl.	$+26.4°$,	a mean	$\Delta\mu$ of	$-0^s.00069$
8	"	"	$+15.1$	"	"	.00086
8	"	"	$+\ 6.0$	"	"	.00082
7	"	"	-16.0	"	"	-0.00071

so that the difference is not a function of declination. A constant $\Delta\mu = -0^s.0008$, within the limits of probable error of the value found, exactly satisfies the difference of the two systems for 1755 as independently deduced. Dr. AUWERS, in the *Berliner Jahrbuch* for 1884, finds a difference between the *A.G.* places and those of the *American Ephemeris* for 1883.0, of about $-0^s.016$ south of declination $+15°$. This would indicate an agreement in 1863 instead of 1868, or a yearly difference greater than $0^s.0008$; but as some of the *Ephemeris* stars "have been derived from recent catalogues without a rigorous reduction for equinox," the discrepancy is probably to be ascribed to the influence of these.

For older catalogues not used by NEWCOMB, the corrections were taken from the reductions to the Wolfers system in ARGELANDER's Vol. VII, with the small addition

$$AG-W = 0^s.0003\ (1828-T)$$

which might have been omitted without considerable error, as those catalogues were allowed small weight. No correction was made to the Harvard places (*Annals*, Vol. XV, part 1) either in the catalogue of 1213 stars, or in the observations of 1883–5. To BECKER's results, and GRANT's, and AUWERS's Bradley, the reductions of Greenwich 1860 were applied. Brussels 1865 received a special discussion. The places of fundamental stars are given in the preface to *Annales Astronomiques*, Tome VI, and differ from NEWCOMB's places for 1865 (*α Canis Maj.* being rejected as before) by

$$N-Q = +0^s.046 + 0^s.031 \cos\alpha - 0^s.036 \sin$$
$$\therefore AG-Q = +0.048 + 0.031 \cos\alpha - 0.036 \sin$$

that is to say, by the corrections to the Greenwich catalogues exaggerated. No variation with declination; the coefficient given by calculation was less than $0^s.0001$ per degree. The probable error of a Brussels fundamental place, corrected by above formula, is $\pm 0^s.014$, accidental error in Newcomb supposed null. Corrections from Newcomb, to stars north of +15° declination, are necessarily more or less uncertain.

The weights given on page 18 of Prof. Newcomb's paper were used where there were 25 observations. For stars less frequently observed, they were diminished, in about the proportion $1 : 1 + \frac{6}{n}$. Greenwich 1872 had a maximum weight of 4; Glasgow 1870 of 1.5; Brussels 2.5; Harvard (each series) 3; Pulkowa 1865 (from Vol. XII of the *Observations*) 7; and Pulkowa 1871 (*Zusatzsterne*) 4. For Pond, Henderson, Robinson and Johnson, the maximum was from 0.5 to 0.8; the weights actually used, as there were usually few observations, rarely rose to half. Piazzi, to whom most of the errors found in the *A.G.* fundamental places are due, is given but 0.1 for all stars, *Groombridge* the same, or 0.2 when the star is observed more than five times.

The table shows the results obtained: w being the weight determined as just explained, the "Epoch" a weighted mean of the authorities consulted.

$$\frac{\Sigma wT}{\Sigma w}, \text{ while } w_\mu = w\left(T - \frac{\Sigma wT}{\Sigma w}\right)^2$$

The correction has the form $\Delta\alpha + (T - 1875)\,\Delta\mu$; and to improve it by the addition of a new authority, of weight w', at epoch T', giving an apparent correction to the *A.G. F.C.* of $\Delta'\alpha$, the following corrections are to be introduced, designating numbers in the third to seventh columns by III to VII, and the numbers substituted by III′ to VII′:

$$\mathrm{III}' - \mathrm{III} = w'$$

$$\mathrm{IV}' - \mathrm{IV} = \frac{w'(T' - \mathrm{IV})}{\mathrm{III}'}$$

$$\mathrm{V}' - \mathrm{V} = \frac{\mathrm{III}}{100}(T' - \mathrm{IV})(\mathrm{IV}' - \mathrm{IV})$$

$$\mathrm{VII}' - \mathrm{VII} = \frac{w'(T' - \mathrm{IV})}{100\,\mathrm{V}'}[\Delta'\alpha - \mathrm{VI} - (T' - 1875)\mathrm{VII}]$$

$$\mathrm{VI}' - \mathrm{VI} = \frac{w'}{\mathrm{III}'}[\Delta'\alpha - \mathrm{VI} - (T' - 1875)\mathrm{VII}] + (1875 - \mathrm{IV}')(\mathrm{VII}' - \mathrm{VII})$$

For example, the effect of rejecting the Greenwich 6-year catalogue from the calculation for star 515 may be found by substituting in these formulas

$w' = -0.8$, $T' = 1853.7$, $\Delta'\alpha = +0^s.366$.

Hence

$\mathrm{III}' = 9$, $\mathrm{IV}' = 1862.7$, $\mathrm{V}' = 24$, $\mathrm{VII}' = -0^s.0019$, $\mathrm{VI}' = +0^s.023$.

F.C. No.	Designation	Σw	Epoch	$\frac{\Sigma w_\mu}{100}$	$\Delta\alpha$	$\Delta\mu$	Remarks
					s	s	
204	ι *Draconis*	22	1860.9	40	+0.033	+0.0008	$\Delta\mu$ by Pulk. Vol. 12. $+0^s.0020$; resid. fm do. (wts. 7,3) $-0^s.033$
209	α *Coronae Bor.*	57	50.9	356	— .003	— .0002	Res. from corr. Newc. (wts. 40,218) $0^s.0001$ (T—1810)
220	θ *Draconis*	27	56.2	95	— .038	— .0021	Res. Pond (wts. 0.4,4) $-0^s.26$; fm Harv. '85 (wts. 1.5,12) $-0^s.135$
221	ς *Herculis*	18	61.3	28	+ .087	+ .0056	$\Delta\mu$ by Pond v. 12, $+0^s.0020$; res. from Piazzi $+0^s.33$
472	19 *Ursae min.*	15	66.7	21	+ .047	+ .0063	Res. from Pond (wts. 0) $-3^s.72$
224	τ *Herculis*	28	61.9	48	+ .041	+ .0036	$\Delta\mu$ by Pond v. 12, $+0^s.0030$
173	ω *Herculis*	12	68.3	16	+ .024	+ .0050	Res. from Piazzi $+0^s.41$
226	ι_1 *Draconis*	37	59.3	72	— .110	— .0086	$\Delta\mu$ by P. v. 12, $-0^s.006$; res. from Piazzi $-0^s.53$
481	*x Herculis*	10	52.9	102	+ .015	+ .0011	$\Delta\mu$ by Auwers's Bradley v. 3. $\pm 0^s.0009$
244	ι *Herculis*	25	58.0	113	— .012	— .0001	$\Delta\mu$ by Auwers's Bradley $+0^s.0001$, by P. v. 12, $+0^s.0005$
255	ο *Herculis*	20	60.3	100	— .009	.0000	$\Delta\mu$ by Auwers's Bradley and P. v. 12, $+0^s.0003$
186	*Groomb.* 2533	8	66.2	10	+ .036	+ .0054	
261	ε *Lyrae*. 4 *sp*	22	49.8	126	+ .016	+ .0022	Res. fm B. (wts. 0.8,72) $+0^s.13$; fm Piaz. $-0^s.12$; fm Grb. $-0^s.27$
262	ε *Lyrae*. 5 *m*	19	46.6	114	+ .009	+ .0008	Res. fm B. (wts. 0.8,67) $+0^s.11$; fm Piaz. $-0^s.43$; fm Grb. $-0^s.21$
194	ι *Lyrae*	15	64.3	104	— .008	— .0002	
196	θ *Lyrae*	13	64.6	50	+ .019	+ .0016	Res. from Brad. (wts. 0.2,24) $+0^s.15$
289	γ *Cygni*	31	51.8	213	— .010	.0000	
505	6 *H Cephei*	8	60.6	20	+ .035	+ .0037	Res. from Grw. 1850 (wts. 0.8,1) $+0^s.273$; from Pulk. 1871 (wts. 4.0,3, sole authority in *F.C.*) $-0^s.049$
515	13 *H Cephei*	10	1862.0	25	+0.038	—0.0026	

The "Remarks" include corrections to the *F.C.* proper-motions from investigations made since its publication, also a few noteworthy residuals. For the star in Newcomb's tables, his places were corrected by the formula, and represented in the equations by two weights of 20 each, at epochs respectively 1824 and 1870, being thus combined with data since published. For the stars ε *Lyrae*, the ancient authorities were numerous, though somewhat discordant. Applying the corrections, we have μ for ε4 $= 0^s.0000$ and for ε5 $= +0^s.0003$, differing by less than the probable error. As there is similar agreement of proper-motions in declination, it is quite probable that the whole group has a common drift, nearly due northward. Each of the stars is supposed to have been observed as one object, unless otherwise stated. The observed point of the pair ε4 is taken at one-third of the distance ($0^s.11$ in R.A.) from the *sp* to the *nf* component, and that of ε5 (dist. $0^s.16$ in R.A.) at midway.

Results given by Mr. Chandler in Vol. XVII of the *Harvard Annals* were not included in this computation. He finds for Nos. 472, 224, 226, $\Delta\alpha = +0^s.312$, $+0^s.118$, $-0^s.177$; residuals therefore, taking his epoch as 1885.5, $+0^s.199$, $+0^s.039$, $+0^s.023$.

Prof. NEWCOMB adopts (page 23 of Appendix 3) a correction of $+0^s.030$ to the preliminary right-ascensions of AUWERS's reduction, on the authority of BESSEL, from BRADLEY's sun-observations. If for this is substituted the value of $+0^s.056$, finally used by AUWERS, the first conditional equation on page 33 becomes $x' - 0^s.64\,y' = +0^s.09$. The effect of introducing this change, and at the same time reducing PIAZZI's weight in the adjustment to 1, is to give for x' $+0^s.021$ in the solution instead of $+0^s.016$, and for y' $-0^s.038$ instead of $-0^s.009$. Applying these, the system would be corrected by $+0^s.008 - 0^s.0003\,(T-1820)$, or $0^s.0003\,(1847-T)$, leaving the *A.G.* system with an outstanding correction of $0^s.0005\,(T-1881)$. No inference from this result seems to be called for, but it is believed to be not without interest; the more particularly in view of the near agreement with it of deductions from nine years' recent observations of the sun at Washington (see *Monthly Notices*, Vol. XLIX. No. 9).

Dr. AUWERS in the *Erläuterungen* to the *A.G.F.C.* says that "the proper-motions will still be the weak point" in it. Confirmation of this is given in the table above, where the same sign is found for $\Delta\alpha$ and $\Delta\mu$. The $\Delta\alpha$ deduced for the epoch in the fifth column of the *F.C.* exceeds a sixtieth of a second in but two cases: $+0^s.022$ for No. 201, where his catalogue of greatest weight is discordant, and $+0^s.019$ for No. 515, where he depends on but one authority.

OCCULTATION OF *JUPITER*, 1889 SEPTEMBER 3.

BY WILLIAM DAWSON.

The disappearance of the satellites was more nearly instantaneous than I had expected, seeming nearly as much so as a star. During immersion, the edge of the moon was sharply marked on the planet, with no appearance of any shady band.

	h m s
Occultation of Satellite III	8 39 10
" " " II	8 44 17
" " " IV	8 49 28
" " " I	8 53 3

Occultation of *Jupiter*

	h m s
First contact	8 50 20
Second "	8 51 13
Fourth "	9 53 10?

The error of local time can hardly exceed five seconds. Approximate latitude = 39° 50′; long. = 85° 25′.

Spiceland, Indiana.

FILAR-MICROMETER OBSERVATIONS OF COMETS 1889 *f* AND *g*.

MADE WITH THE 12-INCH EQUATORIAL OF THE LICK OBSERVATORY.

BY E. E. BARNARD.

1889 Mt. Hamilton M.T.	⁎	No. Comp.	☄ — ⁎ $\Delta\alpha$	☄ — ⁎ $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
			COMET *f* 1889 (SWIFT).					
d h m s			m s	′ ″	h m s	° ′ ″		
Dec. 13 9 17 5	6	6		−6 17.5		+19 29 31.0		0.525
9 36 55	6	20	+1 1.05		23 51 46.01		9.021	
15 9 27 13	7	11 , 5	+0 16.76	−0 3.9	23 58 2.93	+20 3 31.1	9.567	0.530
			COMET *g* 1889 (BORRELLY).					
Dec. 15 7 18 39	1	13 , 7	+0 26.41	−7 54.2	18 10 50.11	+15 30 10.2	9.816	0.681

Mean Places for 1889.0 of Comparison-Stars.

⁎	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
6	23 50 39.98	+1.98	+19 35 28.6	+19.9	Weisse's Bessel XXIII. 1022
7	23 57 11.10	+2.07	+20 3 15.2	+19.8	" " XXIII. 1209
1	18 10 21.59	−0.89	+15 38 0.5	+ 3.9	Lalande 33689

COMET SWIFT.

Dec. 13. Air saturated with moisture. Observation difficult, but good.

Dec. 15. Light of comparison-star interfered with the $\Delta\delta$. Observations good.

COMET BORRELLY.

Dec 15. Comet about 1′¾ diam. Round, gradually brighter in middle, 10th or 11th mag. No nucleus.

Continuous stormy weather has prevented any other observations of these comets.

TABLE OF *h* log *yy*,

In Units of Seventh Place, for Argument *h* in Units of the Fourth for Computation of *yy* by Gauss's Method.

By Rev. GEORGE M. SEARLE.

(*See p.* 112.)

h	Diff.	*h*	Diff.	*h*	Diff.	*h*	Diff.	*h*	Diff.	*h*	Diff.	*h*	Diff.	*h*	Diff.
0	0	30	1200	60	2702	90	4498	120	6583	150	8948	180	11588	210	14498
1	35	31	1245	61	2757	91	4563	121	6657	151	9032	181	11681	211	14599
2	70	32	1291	62	2813	92	4628	122	6732	152	9116	182	11774	212	14701
3	106	33	1337	63	2869	93	4694	123	6807	153	9200	183	11867	213	14803
4	142	34	1383	64	2925	94	4760	124	6882	154	9284	184	11961	214	14906
5	179	35	1430	65	2981	95	4826	125	6957	155	9369	185	12055	215	15008
6	216	36	1477	66	3038	96	4892	126	7033	156	9454	186	12149	216	15111
7	253	37	1524	67	3095	97	4959	127	7110	157	9540	187	12243	217	15215
8	290	38	1572	68	3153	98	5026	128	7186	158	9626	188	12338	218	15318
9	328	39	1620	69	3210	99	5091	129	7263	159	9712	189	12433	219	15422
10	366	40	1668	70	3268	100	5162	130	7340	160	9798	190	12529	220	15526
11	405	41	1716	71	3327	101	5230	131	7418	161	9885	191	12624	221	15631
12	444	42	1765	72	3386	102	5298	132	7495	162	9972	192	12720	222	15736
13	483	43	1814	73	3445	103	5367	133	7573	163	10059	193	12817	223	15841
14	522	44	1864	74	3504	104	5436	134	7652	164	10146	194	12913	224	15946
15	562	45	1914	75	3564	105	5505	135	7731	165	10234	195	13010	225	16052
16	602	46	1964	76	3624	106	5575	136	7810	166	10322	196	13107	226	16158
17	643	47	2015	77	3684	107	5645	137	7889	167	10411	197	13204	227	16264
18	684	48	2066	78	3745	108	5715	138	7968	168	10500	198	13302	228	16370
19	725	49	2117	79	3806	109	5785	139	8048	169	10589	199	13400	229	16477
20	766	50	2168	80	3867	110	5856	140	8129	170	10678	200	13499	230	16584
21	808	51	2220	81	3929	111	5927	141	8209	171	10768	201	13597	231	16691
22	850	52	2272	82	3991	112	5999	142	8290	172	10858	202	13696	232	16799
23	893	53	2325	83	4053	113	6071	143	8371	173	10948	203	13795	233	16907
24	936	54	2378	84	4116	114	6143	144	8453	174	11039	204	13895	234	17015
25	979	55	2431	85	4179	115	6215	145	8535	175	11130	205	13995	235	17124
26	1023	56	2485	86	4242	116	6287	146	8617	176	11221	206	14095	236	17232
27	1067	57	2538	87	4306	117	6361	147	8699	177	11312	207	14195	237	17341
28	1111	58	2593	88	4370	118	6434	148	8782	178	11404	208	14296	238	17451
29	1155	59	2617	89	4434	119	6509	149	8865	179	11496	209	14397	239	17560

OBSERVATIONS OF COMETS *d* AND *g* 1889.

MADE AT THE U.S. NAVAL OBSERVATORY WITH THE 9.6-INCH EQUATORIAL.

By Prof. E. FRISBY.

[Communicated by the Superintendent.]

1889 Washington M.T.	✱	No. Comp.	☄ — ✱ Δα	 Δδ	☄'s apparent α	 δ	log pΔ for α	 for δ
			Comet *d* (Brooks)					
d h m s			m s	′ ″	h m s	° ′ ″		
Nov. 23 9 36 41.6	1	16 , 4	—0 21.44	+3 51.0	23 53 59.82	+ 0 32 32.1	9.547	0.738
Dec. 20 10 6 42.8	2	20 , 2	—1 0.87	—7 9.8	0 25 31.82	+ 5 8 52.5	9.579	0.712
21 7 13 7.0	2	18 , 4	+0 9.75	+2 21.0	0 25 12.43	+ 5 18 23.5	9.003	0.700
23 8 53 19.1	3	20 , 4	—0 33.13	+5 11.6	0 28 34.95	+ 5 40 59.0	9.463	0.695
			Comet *g* (Borrelly)					
Dec. 23 7 2 56.3	4	14 , 3	+1 18.53	+0 12.6	18 19 52.82	+36 51 7.2	9.745	0.539
24 7 10 24.6	5	20 , 4	+0 57.32	+0 43.3	18 20 58.86	+35 39 34.2	9.635	0.748
26 7 11 39.3	6	20 . 4	—3 4.21	—4 48.1	18 24 6.89	+33 28 26.1	9.721	0.760

Mean Places for 1889.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	23 54 19.08	+2.18	+ 0 28 16.3	+14.7	Yarnall (F) 10895
2	0 25 30.59	+2.10 +2.09	+ 5 15 48.2	+14.2 +14.3	Weisse's Bessel (1) O 390
3	0 29 5.97	+2.11	+ 5 35 33.1	+14.3	Approx. place Wash. Tr. C.
4	18 18 34.37	−0.08	+36 50 51.7	+ 2.9	Weisse's Bessel (2) XVIII 199
5	18 20 1.73	−0.19	+35 38 48.8	+ 2.4	" " XVIII 538
6	18 27 11.29	−0.19	+33 33 11.0	+ 3.2	" " XVIII 751

OBSERVED MAXIMA AND MINIMA OF SHORT-PERIOD VARIABLES IN *SAGITTARIUS.*

BY PAUL S. YENDELL.

The observations given below were undertaken during the past summer, in continuation of the series of observations of the stars of this interesting group, the results of which for the summer of 1888 have been published in this Journal, Vol. VIII, p. 119. The great prevalence of cloudy weather during the season, has made the different series so irregular and broken, that scarcely any results were obtained by the usual method of reduction by the single light-curves: consequently, in the absence of any standard mean light-curves of these stars, a resort was necessary to the use of such mean curves as could be deduced from the small number of observations accumulated during this season and that preceding. These curves are strictly provisional in character, and as such are not given here.

The low weights assigned to many of the observed times are due to the scattered character of the observations; a single observation, or two, being frequently all that are available to indicate the phase.

The observations of *V Sagittarii* are here included, although an object of quite another class, principally because they were undertaken simultaneously with those of *U*; the star being in the same field of the telescope, and the same comparison-stars being used.

X Sagittarii.

This star is no. 6368 of CHANDLER's catalogue. Between June 17 and September 27, thirty-one observations were secured, from which the following observed times of maximum and minimum were deduced by the application of a mean light-curve, formed from all the observations obtained in 1888 and 1889.

MAXIMA	W	MINIMA	W
1889 June $15^d.7$	1	1889 June $20^d.7$	2
23.5	3	27.1	1
30.6	3	July 4.9	2
July 6.7	2	19.4	2
14.1	3	24.1	1
Aug. 12.1	3	Aug. 16.0	2
17.9	3	23.1	2
26.1	2	29.9	2
		Sept. 26.2	1

W Sagittarii.

Of this star, which is no. 6472 of CHANDLER's catalogue, thirty-four observations were made from June 17 to Sept. 27, which yield the following maxima and minima by the application of a mean light-curve.

MAXIMA	W	MINIMA	W
1889 June $18^d.2$	3	1889 June $23^d.3$	2
29.0	3	July 1.4	1
July 4.9	2	9.0	1
18.9	2	15.8	2
25.9	3	24.2	3
Aug. 3.0	1		
10.9	1		
17.4	2		
26.2	3		
Sept. 17.3	1		

Y Sagittarii.

No. 6573 of CHANDLER's catalogue. From June 8 to Oct. 18, forty-three observations were obtained, the maxima and minima deduced from which are as follows:

MAXIMA	W	MINIMA	W
1889 June $20^d.3$	1	1889 June $17^d.9$	3
July 1.5	2	24.3	2
6.7	2	29.4	1
18.4	4	July 16.1	4
23.8	1	21.3	1
Aug. 1.9	3	Aug. 20.3	1
10.8	2	30.3	1
15.9	2	Oct. 10.3	1
22.1	3	17.8	1
28.5	1		
Sept. 17.5	1		
21.3	1		

V Sagittarii.

This star is CHANDLER's no. 6633. Its light-fluctuations during the season have been marked and irregular. It was first observed June 30, when its light is estimated to have been $7^M.6$; it decreased slowly, and passed a minimum of $8^M.0$ on July 6, after which it rose to $7^M.5$ about July 21; on August 4, when next observed, it was only $7^M.9$, but rose again to $7^M.5$ on the 16th; was observed again at $7^M.9$ on the 22d, after which it rose quickly and passed a maximum of

$7^{M}.3$ about August 28. From this date it slowly declined with some fluctuations to $8^{M}.3$, at which its light was estimated at the last observation on October 18. Twenty-nine observations were made in all; the star is difficult of observation, owing to its place near a bright star.

U Sagittarii.

This star, which is Chandler's no. 6636, was followed with great interest, and observed as often as possible: between June 18 and October 18, thirty-five observations were obtained, from which fourteen maxima and eight minima were deduced by the use of a mean light-curve, and are given below.

The observed light-range, as noticed in the case of *X Sagittarii* (Vol. VIII, p. 119), falls far short of that indicated by Schönfeld in his *Zweiter Catalog*, the extremes observed being estimated at $7^{M}.7$ at maximum, and $8^{M}.4$ at minimum, a range of seven-tenths of a magnitude only, as against $1^{M}.3$ given by Schönfeld, and which, though he does not distinctly say so, is probably Schmidt's estimate; in the *Catalog* the maximum light is given as $7^{M}.0$; I have never observed it above $7^{M}.7$. The star's bright orange color, however, makes its light difficult to estimate.

Maxima	w	Minima	w
1889 June 18.1	1	1889 June 21.3	2
23.1	2	July 17.9	1
30.6	2	24.8	1
July 6.9	2	Aug. 21.1	1
11.6	1	Sept. 2.6	1
21.6	1	17.3	1
Aug. 3.6	1	30.7	1
16.0	1	Oct. 7.3	1
Sept. 6.4	1		
12.5	1		
19.3	1		
Oct. 3.3	1		
9.9	2		
17.0	2		

Dorchester, Mass., 1889 *November* 2.

RING-MICROMETER OBSERVATIONS OF COMET *d* 1889,

MADE AT THE SHATTUCK OBSERVATORY OF DARTMOUTH COLLEGE.

BY EDWIN B. FROST.

1889 Greenwich M.T.	*	No. Comp.	☄ — * $\Delta\alpha$	☄ — * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
d h m s			m s	′ ″	h m s	° ′ ″		
Aug. 22 17 35 51	*a*	4	+0 15.01	−13 22.2	0 7 18.90	−6 4 39.2	9.164	0.823
Oct. 21 15 21 7	*b*	8 , 6	−0 27.18	− 4 21.6	23 40 22.23	−3 41 0.0	8.989	0.808
15 31 12	*c*	8 , 2	+1 28.28	+ 6 15.9	23 40 21.63	−3 40 54.9	8.989	0.808
23 15 53 23	*d*	8 , 7	+0 32.93	−12 37.6	23 40 16.08	−3 26 30.1	9.218	0.802
24 16 10 23	*d*	16	+0 32.40	− 6 45.1	23 40 15.52	−3 20 37.7	9.311	0.801
25 15 26 26	*d*	5	+0 31.69	− 0 38.8	23 40 17.77	−3 11 31.4	9.135	0.805

Mean Places for 1889.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place.	Authority
	h m s	s	° ′ ″	″	
a	0 7 31.82	+2.07	−5 51 31.6	+14.6	*Astr. Nachr.* no. 2921, p. 302
b	23 40 47.0	+2.39	−3 37.4	+15.2	S.DM. 3°5702
c	23 38 50.97	+2.38	−3 47 26.0	+15.2	Weisse's Bessel XXIII 755
d	23 39 40.79	+2.36 +2.29	−3 11 7.7	+15.2 +15.1	Lamont 1769

The correction for refraction has been considered insignificant, and has only been applied to the declination on Aug. 22, when it amounted to 0″.3.

The correction for proper-motion has also been found to be entirely insignificant.

Hanover, N.H., 1889 *December*.

ELEMENTS OF THE COMET *g* 1889 (*BORRELLY*).

BY GEORGE A. HILL.

From the position telegraphed by Prof. Barnard, one kindly furnished me by Mr. Wendell, by permission of Prof. Pickering, and one by Prof. Frisby, I have computed the following elements of this comet.

The orbit is only approximate, as the period between the first and third observations is but ten days.

$$T = 1890 \text{ January } 26.832$$

$$\left.\begin{aligned} ☊ &= 12^\circ\ 16'\ 14'' \\ \pi &= 209\ \ 38\ \ 49 \\ \omega &= 197\ \ 22\ \ 35 \\ i &= 57\ \ 35\ \ 14 \end{aligned}\right\} \text{Mean Equinox } 1890.0$$

$$\log q = 9.437828$$

Naval Observatory, Washington, 1889 *Dec.* 31.

OBSERVATIONS OF COMET *d* 1889 (*BROOKS*),

MADE AT THE U.S. NAVAL OBSERVATORY.

BY A. HALL.

[Communicated by the Superintendent.]

1889 Washington M.T.	*	No. Comp.	☄ − * Δα	☄ − * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
d h m s			m s	′ ″	h m s	° ′ ″		
Dec. 12 7 0 10.7	1	16 , 5	+2 53.62	+1 21.0	0 13 59.17	+3 41 25.2	8.437	0.703
13 6 37 6.7	2	16 , 5	−1 25.67	+5 4.3	0 15 13.82	+3 51 52.5	*n*8.130	0.701
14 7 23 30.0	3	16 , 5	−3 17.59	−1 42.9	0 16 30.62	+4 2 44.5	8.926	0.700
21 5 58 9.4	4	20 , 6	+0 5.77	+1 44.9	0 25 38.46	+5 17 47.5	*n*8.693	0.685
22 6 0 29.2	5	20 , 6	−0 4.27	+1 38.1	0 27 1.21	+5 28 40.3	*n*8.597	0.683
23 6 47 22.5	6	16 , 5	−0 41.59	+4 12.1	0 28 26.5	+5 39 59.	8.774	0.681

Mean Places for 1889.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	0 11 3.74	+2.11	+3 39 49.7	+14.5	Bonn Observations
2	0 16 37.36	+2.13	+3 46 33.8	+14.4	" "
3	0 19 46.08	+2.13	+4 4 13.0	+14.4	" "
4	0 25 30.59	+2.10	+5 15 48.3	+14.3	Weisse's Bessel O 390
5	0 27 3.38	+2.10	+5 26 47.9	+14.3	" " O 422
6	0 29 6.0	+2.1	+5 35 43.	+14.	DM. +5° 73, approximate

OBSERVATIONS OF COMET *d* 1889 (*BROOKS*),

MADE AT THE HALSTED OBSERVATORY, WITH THE 23-INCH EQUATORIAL AND SQUARE-BAR MICROMETER.

BY PROF. C. A. YOUNG.

1889 Greenwich M.T.	*	No. Comp.	☄ − * Δα	☄ − * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
d h m			m s	′ ″	h m s	° ′ ″		
Dec. 19 11 35.9	1	11	+1 24.40	−5 35.9	0 23 58.2	+4 56.3	8.192	0.708
21 12 53.3	2	12	−0 2.05	−2 7.7	25 45.5	+5 18.8	9.242	0.707
22 12 38.8	3	12	+0 1.20	+2 25.2	27 6.6	+5 29 27.1	9.220	0.695
23 14 10.4	4	13	+0 4.39	+0 25.3	28 33.9	+5 41.5	9.539	0.720
14 10.4	5	13	−1 39.21	−4 8.8	28 34.3	+5 41.6	"	"
25 12 29.9	6	13	−1 3.60	−3 50.5	31 14.0	+6 2.2	9.171	0.699
12 29.9	7	13	−1 35.28	+5 8.3	31 17.8	+6 2.2	"	"
27 11 16.0	8	6	−0 35.03	+3 28.3	34 4.0	+6 23.7	8.505	0.642
11 30.1	8	6	−0 31.07	+3 40.5	0 34 5.0	+6 23.9	8.640	0.692

Mean Places for 1889.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′	″	
1	0 21 31.7	+2.08	+5 1.7	+14.3	Argelander, DM. 4 55
2	25 45.5	+2.09	+5 20.7	+14.3	" " 5 63
3	27 3.31	+2.10	+5 26 47.6	+14.3	Weisse's Bessel O 422
4	28 27.4	+2.10	+5 40.9	+14.3	Argelander, DM. 5 71
5	30 11.4	+2.11	+5 45.5	+14.3	" " 5 76
6	32 15.6	+2.10	+6 5.8	+14.2	" " 5 80
7	32 51.0	+2.10	+5 56.9	+14.2	" " 5 84
8	0 34 36.9	+2.09	+6 20.0	+14.2	" " 6 88

The second observation of Dec. 27 was made by Mr. E. B. FROST.

The comet was easily observable on every night excepting Dec 27, when the moonlight interfered.

On Dec. 19 and 21, the tail was about 2′ in length, the head small and well condensed.

The places of the comparison stars taken from the *Durchmusterung* are reduced only with the corresponding degree of accuracy

Princeton, N.J., 1890 *Jan.* 1.

ELEMENTS AND EPHEMERIS OF COMET *g* 1889 (*BORRELLY*).

By W. W. CAMPBELL.

These elements and ephemeris have been obtained from observations made at Mount Hamilton, Dec. 15, and at Ann Arbor, Dec. 27 and Jan. 4. The constants refer to the mean equinox 1890.0. The brightness at discovery is the unit employed.

From the approximate positions for Feb. 10 and Feb. 20, it appears that observers in the southern hemisphere may be able to see it after perihelion passage.

$$T = \text{Gr. M.T. 1890 Jan. } 26^{d}.18027$$

$$\left.\begin{array}{rcl} \omega & = & 199^{\circ}\ 51'\ 43''.2 \\ \Omega & = & 8\ \ 29\ \ 17\ .0 \\ i & = & 56\ \ 44\ \ 39\ .0 \end{array}\right\} 1890.0$$

$$\log q = 9.430872$$

$$(\text{O}-\text{C}),\quad \cos\beta'\,\Delta\lambda' = +5''.3\ ,\quad \Delta\beta' = +0''.1$$

Ann Arbor, 1890 *January* 4.

Ephemeris for Greenwich Mean Time.

Gr. M.T. 1890	App. α h m s	App. δ ° '	log r	log Δ	Br.
Jan. 11.5	18 40 14	+ 8 7	9.7248	9.9040	7.9
12.5	41 38	6 4			
13.5	43 10	3 58	9.6848	9.9026	9.8
14.5	44 50	+ 1 48			
15.5	46 42	− 0 25	9.6413	9.9036	11.7
16.5	48 17	2 45			
17.5	51 9	5 10	9.5946	9.9071	14.2
18.5	53 52	7 36			
19.5	18 57 0	10 5	9.5458	9.9148	17.2
20.5	19 0 37	12 35			
21.5	4 50	15 5	9.4982	9.9266	20.3
22.5	9 46	17 34			
23.5	15 29	19 58	9.4579	9.9430	22.7
24.5	22 5	22 15			
25.5	29 31	24 23	9.4340	9.9636	23.0
26.5	37 51	26 19	9.4309	9.9751	22.2
27.5	19 46 56	28 0	9.4312	9.9871	20.6
29.5	20 6 43	30 37	9.4586	0.0118	16.5
Jan. 31.5	20 27 19	−32 13	9.4991	0.0360	12.2

SPECTROGRAPHIC OBSERVATIONS OF *ALGOL*.

At the session of the physico-mathematical class of the Berlin Academy of Sciences held November 28, Dr. Auwers presented the following results of the spectrographic observations of the variable star *Algol*, by Professor Vogel and Dr. Scheiner.

Three impressions of the spectrum, taken last winter, had already given evidence that *Algol* recedes from the sun before a minimum, and approaches it after a minimum. Notwithstanding that the lines of the *Algol*-spectrum are not well adapted for accurate measurement, still every impression gave the direction of the motion beyond all doubt, and permitted the determination of its amount with tolerable approximation.

Three new impressions, made within a few weeks, have afforded results completely accordant; and the hypothesis, — long ago proposed but for the most part abandoned since then, on account of the great mechanical and physical difficulties which it entails, — that the variation of *Algol's* light is to be attributed to eclipse by a dark companion revolving around it, now receives strong support again from these observations.

The motion of revolution for the visible star may, from the mean of the six measurements, be assumed as 5.7 geographical miles [42 kilometers*]. Furthermore, the assumption of a circular orbit, described with this velocity, gives when combined with the period of variation, an arrangement of the system somewhat thus: —

Diameter of the principal star	230 000	miles	[1 700 000 km.]
" " dark companion	180 000	"	[1 322 000 "]
Distance of their centers	700 000	"	[5 200 000 "]
Orbital velocity of the companion	12.0		[88 "]

Masses of the two bodies $\frac{4}{9}$ and $\frac{2}{9}$ of the sun's mass.

The several results of the observations now at hand are as follows: —

Potsdam M.T.	d h	Distance from Minimum h	Observed motion toward the earth	Reduction to sun	Star toward sun at observ'n	Observ'd referred to nearest quadrature	Weight
1888 Dec.	4 6.6	11.4 after	−5.0 M	−1.2 M	−6.2 M	−7.1 M	$\frac{1}{2}$
1889 Jan.	6 5.7	22.4 before	+6.9 "	−3.0 "	+3.9 "	+4.3 "	1
"	9 5.5	19.4 before	+7.5 "	−3.1 "	+4.4 "	+4.5 "	1
Nov.	13 9.3	13.3 after	−5.6 "	+0.2 "	−5.4 "	−5.7 "	1
"	23 9.0	22.3 before	+6.2 "	−0.5 "	+5.7 "	+6.5 "	1
"	26 8.5	19.6 before	+6.8 "	−0.7 "	+6.1 "	+6.2 "	$\frac{1}{2}$

Consequently the mean of the observed motions, reduced to quadrature, is

Before minimum, +5.3 miles. After minimum, −6.2 miles.

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*A German geographical mile represents the fifteenth part of a degree on the terrestrial equator, or about 7.4 kilometers.

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Observations of Comet *d* 1889 (Brooks), by Prof. C. A. Young.
Elements and Ephemeris of Comet *g* 1889 (Borrelly), by Mr. W. W. Campbell.
Spectrographic Observations of Algol.

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OBSERVATIONS OF VARIABLE STARS IN 1889.

BY PAUL S. YENDELL.

α Herculis.

Between April 19 and November 30, this star was observed on eighty-nine evenings; the observations show seven maxima and six minima. The star's light-curve, though irregular, has shown no marked peculiarities this year; slight indications of the rapid fluctuations noted by Schmidt were observed about the minimum of July 13. The observed times of maximum and minimum are as follows:

Maxima	Minima
1889 May 3	1889 May 12
23	June 3
June 28	July 13
July 30	Aug. 21
Sept. 19	Sept. 29
Oct. 17	Nov. 7
Nov. 24	

R Scuti.

Seventy-three observations of *R Scuti* were obtained between May 26 and November 30. When first observed, the star's magnitude was estimated as 5.9, from which it declined to a minimum of 6.7 on June 22; from this it increased, with several halts and fluctuations to a rather indefinitely marked maximum on or about August 27, at which time it reached 4.5 magnitude; from this date it decreased slowly to a minimum of 6.2 magnitude on November 18, and when last observed had again increased about half a magnitude.

S Sagittae.

But few observations of this star were made during the summer months; continuous watch of it was begun Sept. 22: fifty-eight observations in all were obtained, which yield, by the use of a mean light-curve, the following maxima and minima.

Maxima	w	Minima	w
1889 May 21.12	2	1889 May 27.90	2
30.65	3	June 4.48	2
June 8.72	1	Sept. 30.65	2
Sept. 25.12	5	Nov. 21.65	1
Oct. 4.71	5		
13.60	5		
21.27	3		
Nov. 5.48	4		
14.98	4		
30.58	3		
Dec. 9.83	4		
18.26	5		

The weights attached to the above times indicate the number of observations from which each was deduced; the same plan has been followed with the other stars mentioned in this paper.

T Vulpeculae.

This star was observed on fifty occasions: from these observations are deduced, by the application of a mean light-curve, nineteen maxima, as follows:

Maxima	w	Maxima	w
1889 Sept. 22.63	2	1889 Nov. 14.86	2
27.68	1	19.56	1
Oct. 1.78	3	23.47	3
6.11	2	27.19	2
10.51	2	Dec. 6.08	2
15.36	3	10.34	2
18.74	1	15.64	3
Nov. 2.27	2	20.20	2
6.78	1	24.83	2
10.88	1		

δ Cephei.

This star has been kept as continuously under observation as the weather would permit, from May 21 to the close of the year; the observations were mostly made with the opera-glass. A series of naked-eye observations was carried on during the months of July and August, but being considered less satisfactory than the opera-glass observations, was then discontinued, and the earlier series returned to; the maxima and minima from June 20 to Sept. 15 are deduced from this set of naked-eye observations.

The weather throughout the entire season has been a great obstruction to all observations of this character, it being frequently impossible to obtain more than one observation of a star during its entire period; this applies as well to the two stars next preceding this one, in this paper.

A number of maxima and minima have been included, with nominal weights, which were indicated by single observations at a light beyond the mean values for those phases.

My own observations not furnishing sufficient material for a definitive light-curve, the standard one of Schonfeld, with his light-scale, has been employed in reducing the observations; thirty maxima and ten minima are deduced from the season's observations, and are appended below.

Maxima	w	Maxima	w	Maxima	w	Minima	w
1889 June 1.39	1	1889 Aug. 13.80	2	1889 Oct. 22.11	3	1889 Aug. 27.99	1
5.01	1	19.46	2	Nov. 2.45	3	Oct. 5.19	2
8.88	1	Sept. 1.37	½	8.28	2	25.72	½
20.98	2	15.32	½	13.38	2	Nov. 6.03	3
July 2.19	1	21.79	3	18.92	2	11.53	2
7.35	1	27.19	3	29.36	3	17.31	½
13.56	3	Oct. 1.86	4	Dec. 4.54	2	Dec. 8.97	2
18.18	3	7.17	3	10.68	2	13.26	½
23.45	1	11.66	3	15.92	2	19.39	½
Aug. 4.40	½	17.33	4	21.26	½	24.25	2

Dorchester, Mass., 1890 *January* 6.

ON A NEW SHORT-PERIOD VARIABLE IN *OPHIUCHUS*,

$17^h\,45^m\,57^s$: $-6°\,6'.7$ (1875.0)

BY EDWIN F. SAWYER.

I beg to announce that I have discovered the star 175 (*U.A.*) *Ophiuchi* to be a variable of short period. The star was first observed (in connection with my revision of the magnitudes of the *Uranometria Argentina*) in a sequence on September 9, 1882, and found to be $6^M.4$ (*U.A.* $6^M.7$). Two observations in 1886 accorded well with the one made in 1882, but a third observation on the evening of August 6, 1888, which gave the magnitude $6^M.95$, led me to suspect variability. Although several other observations were secured before its disappearance, the star was invariably found bright. Subsequent observations, made during the past year, soon established certain variability of the star, and that its period was moderately short. From a careful examination of these latter observations, together with the few isolated ones made in previous years, the range of variation appears to be from $6^M.2$ to $6^M.95$, and the period slightly greater than 17 days.

The provisional elements are:

Maximum, 1882 September 3.50 (Camb. M.T.) $+17^d.14\,E$
Minimum, 1882 August 26.65 " " $+17^d.14\,E$

The following are the observed times of maxima and minima. The column O—C is a comparison with the elements above given.

Observed Maxima				Observed Minima			
E	Camb. M.T.	wt.	O—C	E	Camb. M.T.	wt.	O—C
			d				d
0	82 Sept. 4.71	1	+1.21	87	86 Sept. 29.66	1	+3.83
86	86 " 16.48	1	—0.06	88	Oct. 14.73	1	+1.76
129	88 " 23.00	1	+0.44	125	88 July 6.42	1	—1.73
130	Oct. 10.54	1	+0.84	130	Sept. 2.94	2	+1.09
147	89 July 27.95	3	—0.13	146	89 July 3.29	5	+0.13
148	Aug. 14.38	2	+0.16	147	" 20.43	7	—0.19
149	" 30.92	3	—0.44	149	Aug. 23.71	6	—0.90
150	Sept. 17.51	2	+0.01	151	Sept. 26.99	4	—0.07
152	Oct. 21.58	5	—0.20	152	Oct. 14.13	4	+0.10

Brighton, Mass., 1890 *January* 28.

The characteristics of the light-fluctuations are, a generally uniform and not very rapid increase; a decrease at first uniform and somewhat rapid, followed by a slow and less regular course. The duration of increase is 7.85 days, and that of decrease is 9.29 days.

The readings of the light-curve give the following:

LIGHT-TABLE.

Time from Max.	Light	Time from Max.	Light	Time from Max.	Light
d		d		d	
—8.00	5.4	—2.00	9.9	+1.00	7.2
7.50	5.4	1.50	10.7	4.50	7.0
7.00	5.4	1.00	11.1	5.00	6.7
6.50	5.5	—0.50	11.3	5.50	6.5
6.00	5.5	0.00	11.4	6.00	6.3
5.50	5.6	+0.50	11.3	6.50	6.0
5.00	5.8	1.00	10.9	7.00	5.7
4.50	6.1	1.50	10.6	7.50	5.4
4.00	6.5	2.00	8.7	8.00	5.4
3.50	7.2	2.50	8.1	8.50	5.4
3.00	8.3	3.00	7.7	9.00	5.4
—2.50	8.7	+3.50	7.5	+9.50	5.4

The light-curve appears remarkably flat at minimum, consequently this phase cannot be determined with sharpness from the observations. The comparison-stars used, and the preliminary light-scale adopted, are as follows, the positions being for the mean equinox of 1875.0.

	α	δ	U.A.	Sawyer	L.
	h m s	° ′	M	M	
a = 183 (*U.A.*) *Oph.*	17 50 11	—4 3.8	5.8	5.7	16.1
b = 187 " "	17 52 58	—4 48.4	6.1	6.35	11.2
c = 167 " "	17 37 2	—7 1.2	6.6	6.5	10.0
d = 194 " "	17 56 6	—5 21.3	6.9	6.9	5.1
e = 178 " "	17 45 58	—5 13.8	7.0	6.95	3.1
f* = – " "	17 46 34	—5 53.8	–	7.1	2.0

---

* S.DM. 5°4523 $7^M.2$

SUN-SPOT OBSERVATIONS,

MADE AT BRYN MAWR, PA., WITH 3-INCH EQUATORIAL.

By A. W. QUIMBY.

1889	Grs.	Sps.	Faculae Grs.	Def.
July 1	0	0	0	poor
3	0	0	0	"
4	0	0	0	fair
5	0	0	0	"
6	0	0	0	good
7	0	0	2	"
8	0	0	0	"
9	0	0	0	"
10	0	0	0	poor
11	0	0	0	"
12	1	2	0	fair
13	1	2	2	"
14	1	1	1	good
15	3	28	0	poor
16	3	23	0	good
17	3	32	0	"
18	3	17	0	poor
19	2	25	1	‘
20	2	25	1	good
21	1	13	2	poor
22	1	6	1	"
23	1	6	1	fair
24	1	1	1	poor
25	0	0	0	fair
26	0	0	0	poor
27	0	0	0	very poor
28	1	8	0	fair
29	0	0	0	poor
30	0	0	0	"
31	1	5	0	fair
Aug. 1	1	5	0	poor
2	1	5	0	fair
3	2	2	0	good
4	2	2	0	poor
5	2	10	0	good
6	1	49	0	"
7	1	57	0	"
8	1	37	0	fair
9	2	8	many	poor
10	3	18	"	fair
11	2	11	"	good
12	2	11	0	poor
13	2	28	0	fair
14	2	20	0	poor
15	2	10	0	"
16	2	25	many	fair
17	2	12	0	fine
18	1	1	0	good
19	2	2	0	"
20	2	2	0	"
21	1	1	0	"
22	0	0	some	fair
23	0	0	"	"
24	0	0	0	"
Aug. 25	0	0	0	poor
26	1	1	0	"
27	1	1	some	fair
28	1	1	"	"
29	1	1	"	"
30	1	1	"	"
31	1	1	0	"
Sept. 1	1	1	0	fair
2	1	1	0	fine
3	1	2	0	"
4	1	1	0	good
5	1	1	0	"
6	1	1	0	poor
7	3	3	some	"
8	2	5	"	"
9	0	0	0	"
14	0	0	0	"
15	0	0	0	"
16	0	0	0	"
17	0	0	0	"
18	0	0	0	"
19	0	0	0	"
20	0	0	0	"
21	0	0	0	"
22	0	0	0	good
23	0	0	0	"
26	2	6	0	poor
27	2	6	0	good
28	2	6	0	"
29	2	7	0	"
30	1	1	0	poor
Oct. 1	2	10	0	poor
2	3	11	0	good
3	3	6	many	"
4	1	1	"	"
5	0	0	"	"
6	0	0	0	poor
7	0	0	0	good
8	0	0	0	"
9	0	0	0	"
10	0	0	0	fair
11	0	0	0	"
12	0	0	0	"
14	0	0	0	poor
15	0	0	0	"
16	0	0	0	good
17	0	0	0	"
18	1	1	5	"
19	1	1	5	"
20	0	0	0	fair
21	0	0	5	good
22	0	0	0	"
23	0	0	0	poor
Oct. 24	0	0	0	poor
27	0	0	0	fair
28	0	0	0	poor
30	0	0	0	"
31	0	0	0	"
Nov. 1	0	0	0	fair
3	0	0	0	poor
4	0	0	0	good
5	0	0	0	poor
6	0	0	0	"
7	0	0	0	"
10	0	0	0	"
12	0	0	0	fair
14	0	0	0	"
15	0	0	0	"
16	0	0	0	"
17	0	0	0	"
20	0	0	0	poor
21	0	0	0	"
22	0	0	0	"
23	0	0	0	good
24	0	0	0	"
26	0	0	0	"
28	0	0	0	"
29	0	0	0	"
30	0	0	0	"
Dec. 1	0	0	0	good
2	0	0	0	fair
3	0	0	0	"
4	0	0	0	good
5	0	0	0	fair
6	0	0	0	good
7	0	0	0	"
8	0	0	0	poor
9	0	0	0	good
10	0	0	0	"
11	0	0	0	poor
12	1	3	0	good
13	0	0	0	"
16	0	0	0	"
19	1	1	some	fair
21	1	1	0	"
22	0	0	0	poor
23	0	0	1	"
24	1	8	0	fair
25	1	21	0	good
26	1	15	0	poor
27	1	15	0	good
28	2	16	some	"
29	2	8	0	fair
30	1	1	0	poor
31	1	1	0	good

EPHEMERIS OF COMET *d* 1889,

(Continued from page 118.)

By WILLIAM BELLAMY.

Gr. M.T.	App. α	App. δ	log *r*	log Δ	Br.
1890	h m s	° ′			
Feb. 3.5	1 35 31	+13 28.9	0.3447	0.3635	0.35
4.5	37 19	39.8			
5.5	39 5	13 50.7			
6.5	40 51	14 1.5			
7.5	42 38	12.3	0.3476	0.3712	0.33
8.5	44 25	23.0			
9.5	46 12	33.7			
10.5	47 59	44.4			
11.5	49 47	14 55.0	0.3506	0.3846	0.31
12.5	51 35	15 5.6			
13.5	1 53 23	+15 16.1			
Feb. 14.5	1 55 12	+15 26.6			
15.5	57 1	37.1	0.3536	0.3948	0.29
16.5	1 58 50	47.5			
17.5	2 0 39	15 57.9			
18.5	2 29	16 8.2			
19.5	4 19	18.5	0.3566	0.4017	0.27
20.5	6 9	28.7			
21.5	7 59	38.9			
22.5	9 50	49.0			
23.5	2 11 41	+16 59.1	0.3597	0.4144	0.26

EPHEMERIS OF COMET *g* 1889, (*BORRELLY*),

By W. W. CAMPBELL.

I send a continuation of the ephemeris of the comet *g* 1889 from the elements already given in no. 209.

An observation made this morning shows the corrections to the computed place to be —0s.47 and +4″.3. Hence I infer that no new determination of the orbit is yet needed, and that it may be well to extend the ephemeris since the larger telescopes even in northern latitudes will probably be able to follow the comet through the greater part of February.

The constants for the equator are

$$x = [9.996667]\, r \sin(294^\circ\, 32'\, 26''.1 + v)$$
$$y = [9.328886]\, r \sin(239\;\; 16\;\; 50.2 + v)$$
$$z = [9.993331]\, r \sin(203\;\; 16\;\; 55.4 + v)$$

Ephemeris for Greenwich Mean Time.

Gr. M.T.	App. α	App. δ	log *r*	log Δ	Br.
1890	h m s	° ′			
Jan. 31.5	20 27 19	—32 13	9.4991	0.0360	12.2
Feb. 2.5	20 47 24	33 1	9.5468	0.0590	8.8
4.5	21 6 13	33 13	9.5955	0.0807	6.4
6.5	23 26	33 0	9.6422	0.1009	4.7
8.5	39 2	32 30	9.6856	0.1200	3.5
10.5	21 53 8	31 49	9.7256	0.1379	2.7
12.5	22 5 51	31 2	9.7622	0.1548	2.1
14.5	17 22	30 11	9.7959	0.1708	1.7
16.5	27 50	29 17	9.8268	0.1859	1.4
18.5	37 24	28 23	9.8554	0.2003	1.1
20.5	46 12	27 28	9.8819	0.2140	0.9
22.5	22 54 17	26 35	9.9066	0.2271	0.8
24.5	23 1 17	25 42	9.9296	0.2396	0.7
Feb. 26.5	23 8 40	—24 50	9.9512	0.2515	0.6

EPHEMERIS OF VARIABLES OF THE *ALGOL*-TYPE.

Approximate Greenwich M.T., 1890.

	February		February		February		February		March
	d h		d h		d h		d h		d h
U Cephei	3 19	*U* Coronae	11 20	*U* Cephei	18 18	*U* Cephei	28 17	Algol	7 12
R Can. Maj.	3 19	*Y* Cygni	12 10	*R* Can. Maj.	19 17			*U* Ophiuchi	7 17
S Cancri	6 6	Algol	12 13	*U* Cephei	21 6		March	*Y* Cygni	8 9
U Cephei	6 7	*U* Cephei	13 18	*Y* Cygni	21 10	*Y* Cygni	2 9	δ Librae	9 17
Y Cygni	6 10	Algol	15 10	δ Librae	23 18	δ Librae	2 17	*Y* Cygni	9 21
Algol	6 20	*Y* Cygni	15 10	*U* Cephei	24 18	*Y* Cygni	3 21	Algol	10 8
R Can. Maj.	8 8	*S* Cancri	15 17	*R* Can. Maj.	24 6	*U* Coronae	4 13	*U* Cephei	10 17
U Cephei	8 19	*U* Cephei	16 6	*Y* Cygni	24 10	Algol	4 15	*Y* Cygni	11 9
Y Cygni	9 10	*R* Can. Maj.	16 7	*S* Cancri	25 5	*R* Can. Maj.	5 6	*U* Ophiuchi	11 22
R Can. Maj.	9 11	δ Librae	16 18	*R* Can. Maj.	25 10	*Y* Cygni	5 9	*U* Ophiuchi	12 18
Algol	9 16	*R* Can. Maj.	17 10	*U* Coronae	25 15	*U* Cephei	5 17	*Y* Cygni	12 21
δ Librae	9 19	Algol	18 7	*U* Cephei	26 6	*R* Can. Maj.	6 9	*R* Can. Maj.	14 8
R Can. Maj.	10 14	*Y* Cygni	18 10	*R* Can. Maj.	26 12	*S* Cancri	6 17	*Y* Cygni	14 9
U Cephei	11 7	*R* Can. Maj.	18 14	*Y* Cygni	27 10	*Y* Cygni	6 21	*U* Coronae	14 22
R Can. Maj.	11 18	*U* Coronae	18 18	*R* Can. Maj.	27 16	*R* Can. Maj.	7 12	*R* Can. Maj.	15 11

	March		March		March		April		April
	d h		d h		d h		d h		d h
U Cephei	15 16	δ Librae	23 16	λ Tauri	31 10	*U* Cephei	9 15	δ Librae	20 14
Y Cygni	15 21	*R* Can. Maj.	24 13			*R* Can. Maj.	10 14	*Y* Cygni	20 19
S Cancri	16 4	*Y* Cygni	24 20		April	*U* Coronae	11 13	*U* Ophiuchi	22 20
R Can. Maj.	16 15	*S* Cancri	25 16	*R* Can. Maj.	1 12	*Y* Cygni	11 20	*S* Cancri	23 3
δ Librae	16 17	*U* Cephei	25 16	*R* Can. Maj.	2 15	*U* Ophiuchi	12 19	*U* Ophiuchi	23 16
Y Cygni	17 9	*Y* Cygni	26 8	*U* Ophiuchi	2 17	*S* Cancri	13 15	*Y* Cygni	23 19
U Ophiuchi	17 19	λ Tauri	27 11	*Y* Cygni	2 20	δ Librae	13 15	*U* Cephei	24 14
Y Cygni	18 21	Algol	27 13	*S* Cancri	4 3	*U* Ophiuchi	13 15	*U* Coronae	25 8
λ Tauri	19 13	*Y* Cygni	27 20	λ Tauri	4 9	*U* Cephei	14 14	*R* Can. Maj.	26 12
Y Cygni	20 9	*U* Ophiuchi	27 20	*U* Coronae	4 15	*Y* Cygni	14 20	*Y* Cygni	26 19
U Cephei	20 16	*U* Ophiuchi	28 16	*U* Cephei	4 15	*R* Can. Maj.	17 10	δ Librae	27 14
U Coronae	21 19	*U* Coronae	28 17	*Y* Cygni	5 20	*U* Ophiuchi	17 20	*R* Can. Maj.	27 15
Y Cygni	21 21	*Y* Cygni	29 8	δ Librae	6 15	*Y* Cygni	17 20	*U* Ophiuchi	28 17
R Can. Maj.	22 7	*R* Can. Maj.	30 6	*U* Ophiuchi	6 22	*U* Coronae	18 10	*U* Cephei	29 13
U Ophiuchi	22 19	Algol	30 10	*U* Ophiuchi	7 18	*Y* Cygni	8 20	*U* Coronae	29 19
Y Cygni	23 8	*U* Cephei	30 15	λ Tauri	8 8	*R* Can. Maj.	18 13	*Y* Cygni	29 19
R Can. Maj.	23 10	δ Librae	30 16	*R* Can. Maj.	8 8	*U* Ophiuchi	18 16		
λ Tauri	23 12	*Y* Cygni	30 20	*U* Ophiuchi	8 14	*U* Cephei	19 14		
U Ophiuchi	23 15	*R* Can.Maj.	31 9	*R* Can. Maj.	9 11	*R* Can. Maj.	19 16		

OBSERVATIONS OF COMET *d* 1889,

MADE AT THE HAVERFORD COLLEGE OBSERVATORY, WITH THE 10-INCH EQUATORIAL.

BY F. P. LEAVENWORTH AND D. P. HIBBERD.

1889–90 Haverford M.T.	*	No. Comp.	☄ — * Δα	☄ — * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ	Obs.
d h m s			m s	′ ″	h m s	° ′ ″			
Oct. 15 9 12 28	1	22 , 6	−0 39.13	−0 5.1	23 11 22.17	−4 8 56.5	*n*8.992	0.787	L
Nov. 14 10 1 7	2	16 , 4	−1 57.33	+5 56.8	23 17 15.14	−0 47 11.1	9.334	0.759	L
16 9 2 9	3	20 , 4	−0 35.81	−0 18.9	23 18 32.17	−0 31 2.4	9.059	0.757	H
Jan. 13 8 53 33	4	6 , 1	+1 21.76	–	0 58 39.55	–	9.560	–	L
8 53 33	5	6 , 1	+0 51.32	−4 35.0	0 58 38.97	+9 26 27.7	9.560	0.690	L

Mean Places for 1889.0 and 1890.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	23 41 59.17	+2.13	−1 9 6.6	+15.5	Lalande 46612
2	23 49 10.22	+2.25	−0 53 52.9	+15.0	Yarnall 10817
3	23 19 5.75	+2.23	−0 30 28.4	+14.9	Valentiner
4	0 57 18.86	−1.07	–	–	Yarnall 546
5	0 57 48.72	−1.07	+9 31 8.3	− 5.6	Yarnall 556

On Nov. 14, Nov. 16 and Jan. 13, the comet was very faint, and difficult to observe. Star 2 is Lamont 9344, but the declination is too great by about a minute.

On Oct. 15, a companion was observed $19^{s}.70$ following, and a little north of the nucleus of the comet.

OBSERVATIONS OF COMET *f* 1889 (*SWIFT*),

MADE AT THE HALSTED OBSERVATORY, PRINCETON, N.J., WITH THE 23-INCH EQUATORIAL AND SQUARE-BAR MICROMETER

BY PROF C. A. YOUNG

1889 Greenwich M.T.	*	No. Comp.	☄ — * Δα	☄ — * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
d h m			s	′ ″	h m s	° ′ ″		
Dec. 21 13 11.0	1	6	−14.92	− 7 57.0	0 16 58.46	+21 38 32.3	8.346	0.497
22 13 40.0	2	20	+22.12	−11 25.1	0 20 22.12	+21 54 23.0	8.433	0.517
23 13 10.2	4	6	− 8.75	− 5 20.8	0 23 10.5	+22 10.2	8.253	0.190
13 30.8	3	10	+33.78	+ 1 17.8	0 23 11.1	+22 8.8	8.411	0.506
13 30.8	4	10	− 6.03	− 5 8.7	0 23 13.3	+22 10.4	8.411	0.506

Mean Places for 1889.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place.	Authority
	h m s	s	° ′ ″	″	
1	0 17 11.29	+2.09	+21 46 9.2	+20.1	Lal. 124, Paris Observ. 1874 Nov. 2
2	0 19 59.09	+2.11	+22 5 28.0	+20.1	Struve, *Positiones Mediae* 161
3	0 23 8.2	+2.12	+22 7.2	+20.1	Argelander DM. 21°19
4	0 23 17.2	+2.13	+22 15.2	+20.1	" " 22°70

The observations are corrected for instrumental errors, refraction and motion of the comet. The comet was nearly round, from 2′ to 3′ in diameter, ill-defined, without any trace of a tail, and only slightly condensed at the center. It was very faint, and Dec. 23, especially, was an extremely difficult object to observe. The declinations of the two comparison-stars used Dec. 23, as deduced from the DM., are, it will be observed, considerably discrepant; judging from the apparent error of the ephemeris the second star (22 70) is wrong. The correction of the ephemeris (*A J.* 208) is about $-1^m\ 40^s$ in α, and $-7'$ in δ.

FILAR-MICROMETER OBSERVATIONS OF COMET *g* 1889 (*BORRELLY*),

MADE WITH THE 12-INCH EQUATORIAL OF THE LICK OBSERVATORY.

BY E. E. BARNARD.

1889 Mt. Hamilton M.T.	*	No. Comp.	☄ — *		☄'s apparent		log $p\Delta$	
			$\Delta\alpha$	$\Delta\delta$	α	δ	for α	for δ
h m s			m s	′ ″	h m s	° ′ ″		
Dec. 15 7 18 39	1	13 , 7	+0 26.41	−7 54.2	18 10 50.11	+45 30 10.2	9.816	0.684
17 7 25 46	2	6 , 5	+3 7.89	+5 42.2	18 13 14.64	+43 24 9.9	9.794	0.713

Mean Places for 1889.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	18 10 24.59	−0.89	+45 38 0.5	+3.9	Lalande 33689
2	18 10 7.53	−0.78	+43 18 24.7	+3.0	Weisse's Bessel XVIII, 258, 9

Dec. 15. Comet pretty bright, round, 2′ ± diameter, vgbM 10^M ±. No nucleus.

Dec. 17. Comet pretty bright, round, 2′ ± diameter, vgbM 10^M ±. No nucleus.

The unprecedently bad weather has prevented any other observations of the comet.

It is now too near the sun to be observed.

AN ERROR IN CHAUVENET'S ASTRONOMY.

BY HERBERT A. HOWE.

At the bottom of p. 689 of Vol. I of CHAUVENET's Astronomy is the formula

$$k = \tfrac{1}{2}(\alpha' - \alpha'') \cos\delta.$$

in which k denotes the constant of aberration, while α' and α'' are respectively the right-ascensions of a star. When the effect of aberration in right-ascension reaches its maximum and minimum, these right-ascensions have been freed from the effects of nutation and precession in the interval. δ is the declination. This formula is not a general one, as is shown below.

Let α be the mean right-ascension of the star at any epoch, + the nutation + the proper motion; let ε denote the obliquity of the ecliptic; let m and M be determined by the equations

$$m \sin M = \sin\alpha$$

$$m \cos M = \cos\alpha \cos\varepsilon$$

From equation (721) of CHAUVENET we readily derive

$$\alpha' = \alpha + km \sec\delta, \quad \text{and}$$

$$\alpha'' = \alpha - km \sec\delta, \quad \text{whence}$$

$$mk = \tfrac{1}{2}(\alpha' - \alpha'') \cos\delta.$$

Now $m^2 = \sin^2\alpha + \cos^2\alpha \cos^2\varepsilon$, and m is therefore equal to unity only when $\alpha = 6^h$ or 18^h. Hence CHAUVENET's formula is not generally true. It would be easy to show from the first equation of (675) that the formula

$$k = \tfrac{1}{2}(\lambda' - \lambda'') \cos\beta$$

is true, λ' and λ'' denoting respectively the maximum and minimum values of the longitude of the star, while β is its latitude.

SUN-SPOT OBSERVATIONS,

MADE AT HAVERFORD COLLEGE OBSERVATORY, WITH 8-INCH EQUATORIAL

BY F. P. LEAVENWORTH.

1889	Time	Grs.	Sps.	Size and Def.
July 3	3	1	4	small ; poor
5	12	1	1	" "
6	1	0	0	"
8	12	0	0	"
11	3	1	2	good
12	1	2	10	1 large ; "
14	4	2	17	" "
15	12	2	11	" "
16	11	2	11	" "
17	12	2	10	" "
18	10	2	22	" "
20	10	1	17	" poor
22	10	1	2	" "
23	10	1	1	" good
24	10	1	1	" "
25	10	1	1	small ; "
29	11	2	22	" "
30	10	2	22	" "
31	3	1	23	" poor
Aug. 1	11	1	22	small ; poor
2	10	2	26	2 large ; "
3	10	2	35	" good
4	3	1	21	" poor
5	3	1	24	" "
6	9	1	26	" good
7	10	1	50	" "
8	9	2	24	3 large ; "
10	1	3	20	4 " poor
11	9	3	26	1 " good
12	10	2	9	2 " poor
13	9	2	30	1 " good
14	11	2	12	4 " "
15	1	2	14	3 " "
16	9	2	12	3 " "
17	11	2	6	3 " "
18	9	1	1	1 " "
19	10	2	2	"
20	10	1	1	"
Aug. 21	9	1	1	
22	10	0	0	poor
23	9	0	0	"
24	10	0	0	good
25	4	0	0	"
26	11	1	1	large ; poor
Sept. 9		0	0	poor
14		0	0	"
16		0	0	"
17		0	0	"
18		0	0	"
19	9	0	0	"
21	10	0	0	"
22	3	0	0	good
23	10	1	6	1 large ; "
26	11	1	6	" poor
27	9	1	12	" "
28	10	1	15	" good
29	9	1	7	" "
30	10	1	6	" poor
Oct. 1	10	1	5	1 large : poor
2	9	1	11	" good
3	12	1	4	"
4	12	1	1	poor
5	12	0	0	"
7	10	0	0	"
8	10	0	0	"
9	10	1	1	small : good
10	11	1	8	" "
11	11	0	0	poor
12	10	0	0	good
15	3	0	0	poor
16	10	1	5	small "
17	10	1	12	" good
18	10	1	2	" "
19	10	0	0	"
20	9	0	0	"
Oct. 21	10	0	0	poor
22	10	0	0	"
24	10	0	0	"
30	11	0	0	"
Nov. 1	10	0	0	poor
3	5	0	0	"
4	12	0	0	good
5	9	0	0	"
6	9	0	0	"
7	9	0	0	"
10	10	0	0	"
12	9	0	0	"
14	9	1	1	small "
15	10	1	1	" "
16	10	0	0	poor
22	10	0	0	good
23	10	0	0	"
24	10	0	0	"
26	10	0	0	poor
28	10	2	4	small : good
29	9	2	2	" "
Dec. 1	12	0	0	good
2	10	0	0	poor
4	11	0	0	"
12	3	1	1	large : good
13	11	0	0	"
16	9	0	0	poor
19	9	2	9	"
21	10	3	37	small : good
23	12	1	1	" "
24	12	1	6	"
25	11	1	20	1 large : poor
26	11	1	13	" "
27	11	2	23	2 large : good
28	11	2	21	" "
31	11	1	1	large : poor

OBSERVATIONS OF COMET *g* 1889 (*BORRELLY*).

MADE WITH THE 6-INCH EQUATORIAL OF THE DETROIT OBSERVATORY.

BY W. W. CAMPBELL.

1889-90 Greenwich M.T.	✱	No. Comp.	☄ − ✱		☄'s apparent		log *p* Δ	
			Δα	Δδ	α	δ	for α	for δ
d h m s			m s	′ ″	h m s	° ′ ″		
Dec. 26 23 11 57	1	6 , 8	+3 4.07	−5 6.8	18 23 36.06	+32 38 22.3	*n*9.713	0.727
Jan. 3 23 35 40	2	11 , 7	+1 39.87	+1 29.7	18 31 13.59	+21 25 26.5	*n*9.668	0.717
13 23 48 59	3	9 , 7	−2 17.89	−0 2.6	18 13 57.68	+ 2 54 16.3	*n*9.623	0.765
16 0 6 9	4	7 , 3	−0 16.80	+3 27.7	18 17 42.64	− 1 37 28.2	*n*9.609	0.777

Mean Places for 1889.0 and 1890.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	18 20 32.15	−0.16	+32 13 27.8	+1.3	Leiden Zones 85.19 and 87.20
2	18 30 5.99	−2.27	+21 23 59.3	−2.5	$\frac{1}{3}$(2 Armagh 2237 + Bonn 21°3483)
3	18 46 17.77	−2.20	+ 2 54 23.1	−1.2	Schj. 6997, 8, 9
4	18 48 31.63	−2.19	− 1 10 51.8	−1.1	Göttingen 5135, 6

Jan. 16. Frequent interference from clouds.

OBSERVED MAXIMUM OF *U GEMINORUM*,

BY PAUL S. YENDELL.

The watch for this remarkable variable was begun this season on Oct. 18, and it has been looked for since that date upon every available occasion.

On the evening of 1890 Jan. 14, after an enforced interruption of three weeks, occasioned by illness, the telescope was turned upon this region, when *U* was at once seen, and its magnitude estimated at $9^{\mathrm{M}}.8$. The next evening proved cloudy, but on Jan. 16 another observation was obtained, showing an increase of 0.7 magnitude, to $9^{\mathrm{M}}.1$; the star passed its maximum at $9^{\mathrm{M}}.0$ on Jan. 17.4, Cambridge mean time; on the 18th it had fallen to $9^{\mathrm{M}}.1$, at which its magnitude continued until the 21st; on the 22d it showed a sharp fall of 1.3 magnitude to $10^{\mathrm{M}}.4$; the next evening unfortunately proved snowy, and when looked for on the 24th, the star was invisible in my telescope, though BAXENDELL's comparison-star *f*, estimated by him at $11^{\mathrm{M}}.2$, was well seen, and several of the smaller stars in the field held at times.

Seven observations in all were obtained, as follows: the magnitudes were carefully estimated by comparison with those of BAXENDELL, whose comparison-stars were used.

		h	m	Mag.	
1890 Jan.	14	9	15	9.8	
	16	7	15	9.1	
	17	7	0	9.0	
	18	8	25	9.1	
	20	8	0	9.1	
	21	7	15	9.1	
	22	7	0	10.4	[easily seen
	24	7	5	not seen — star of $11^{\mathrm{M}}.5$	

Dorchester, Mass., 1890 *Jan.* 29.

CORRIGENDA.

No. 209, pages 132, 136, in Heading of table and Index, for *h* log *yy*, put *h* — log *yy*.

In previous observations made at Princeton, the signs of log *p*Δ for *a* should be reversed in the observations of Nov. 23, 25 and 26, 1889 (*A.J.* No. 207.) Also, in the observation for Dec. 19 (*A.J.* 209), in the comet's apparent *a*, for 23^{m} read 22^{m}.

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INVESTIGATION OF ERRORS IN LACAILLE'S *COELUM AUSTRALE STELLIFERUM*.

BY B. A. GOULD.

I.

When determining the places of stars for the *Argentine General Catalogue*, the earliest working-list was afforded by the catalogue constructed from LACAILLE's observations under the superintendence of HENDERSON and by means of his reduction-tables, at the expense of the British Association for the Advancement of Science, and which was published in 1847. A considerable number of the stars there given were found to be either missing or in positions so different from their catalogue-places as to make their identity very uncertain. But since no copy of LACAILLE's original observations was accessible, it was not in my power to detect the sources of these discordances.

In the summer of 1876, being in London, I mentioned this embarrassment to my friend Mr. HIND, who most kindly procured for me the loan of a copy of the *Coelum Australe Stelliferum*, with permission to take it to Cordoba for a few months. And early in the year 1877, I had the gratification of receiving a copy of the same work, generously presented to the Argentine National Observatory by the Council of the Royal Astronomical Society.

It thus became possible to undertake the eminently desirable investigation of the origin of the discordances mentioned; and it was in this way that the large proper motion of the star Lac. 9352 was made manifest.

The examination into LACAILLE's errors of observation proved, however, too laborious and time-consuming to be completed at Cordoba; and I therefore brought the data home with me for further study. This has gone forward since then, as opportunity has permitted; and at present there are but few cases where LACAILLE's recorded observations are neither accordant with the sky within reasonable limits, nor susceptible of explanation by supposing some not improbable error of record, computation or typography.

In August, 1889, I availed myself of a visit to Paris, to compare the original manuscript of LACAILLE's work which is preserved at the Observatory there; access to this and to other ancient records being cordially afforded, and every facility for their study given by the Director and officers. It is evident, however, that the *Coelum Australe*, as printed, is a very accurate reproduction of the original; and the only apparent error which came to light results from an ambiguity in the manuscript figures. But the original is clearly a fair copy, only, of the notes made upon some other paper at the time of observation, so that it furnishes no means of verifying or disproving the assumptions which I had made as to the origin of the errors.

In the preparation of the Catalogue published under the editorship of BAILY, sundry assumptions were made, as to errors in LACAILLE's record. These were inferred from a comparison of the resultant positions with those contained in catalogues already published, and consequently relate to the brighter stars only. For 2 stars, an error of 20^s was assumed in the time of ingress or egress; for 30 stars, an error of 1^m; for 4 stars, one of 10^m; and for 1 star, one of 20^m. Of these 37 arbitrary corrections, all except 2 appear to be fully justified; but for nos. 1010 and 6828, 10^s was subtracted from the recorded time of egress, whereas it should have been added to that of ingress, — the result being that the deduced right-ascension is 10^m too small for each of these stars. There are likewise 11 suggestions of similar error, which were not adopted in computing the catalogue-places; 9 of these suggestions being proved correct by later observations, and 2 of them, those for nos. 5190 and 7897, being found erroneous. Furthermore, 5 stars were assumed to have been observed in the other half of the reticule than that for which they were recorded, — and all these assumptions have been justified by subsequent observation.

Those stars of the English Catalogue which are recorded as not fainter than the sixth magnitude, or are situated within 10° of the ecliptic, were included by BAILY in his compilation of the *British Association Catalogue*, and were reobserved by MACLEAR at the Cape of Good Hope. In volumes XX and XXI of the *Memoirs of the Royal Astronomical Society*, MACLEAR gave a list of cases in which the results of his observations were discordant from the positions of this catalogue; and for most of these was able to indicate the origin of the error.

Finally, ARGELANDER has given in vol. VII of the *Bonn*

Observations a series of corrections to the same catalogue, indicated by his observations in the Southern zones, which extended to beyond the southern tropic; and for a large proportion of these he was able to indicate the source of error in the original records of the *Coelum Australe*.

Those of Lacaille's stars which were not found in their catalogue-positions, at the time of the attempted reobservation of them at Cordoba, were to a large extent identified by means of the zone-observations which had been made there, and embraced all the region included in the *Coelum Australe* as far as 80° of declination. For most of these stars, the original mistake could be detected with a good degree of probability; yet there are many cases where my best efforts failed, and yet more where no explanation of the error has been discovered, except by some supposition for which there is no other evidence than that, while not intrinsically improbable, it appears to be the only mode of reconciling Lacaille's record with the sky.

That stars, observed by Lacaille in 1751, may not now be visible, is of course possible; but repeated observations have convinced me of the extreme improbability that any case of large discordance in position is referable to undetected proper motion.

Believing that Lacaille's noble series of observations, which appear to be of remarkable accuracy when his very limited equipment is considered, may afford still farther important aid to various astronomical investigations, I have been convinced that time is well bestowed, when given to the detection of the errors in his record, so as to permit the reproduction of the observations which he really made. The task of determining the true form and dimensions of his reticules, as well as their focal distance on each night, will thus, I trust, be essentially lightened; and the construction of far more accurate reduction-tables made possible. (See Argelander's remarks, *Bonn Observations*, vol. VII, p. 6.)

The larger part of the mistakes in the *Coelum Australe*, which later observations have revealed, may be referred to errors of one or more full minutes, or of some smaller multiple of ten seconds, in the recorded ingress or egress of a star; there are also a few cases in which the error is of 15^s or 45^s. Another frequent source of error is to be found in an interchange of the times of egress of stars which were in the field of the telescope at the same time. In such cases the interchange is here usually assigned to the moments of ingress or egress, according as the one or the other may serve to retain the earlier catalogue-number for the star which precedes, so that confusion may be avoided in the numeration. Moreover, the cases are relatively numerous in which observations made in one part of the reticule are recorded as made in the other.

There are, likewise, errors clearly referable to mistakes in transcription from the original notes: the most remarkable of these being upon page 43, — where six stars, observed in the lower part of the reticule, 1751 Dec. 16, are recorded one hour too early. This blunder, which exists in the original manuscript, and passed into the catalogue published by Lacaille himself, may easily be recognized on simple inspection; yet it seems to have remained unnoticed until the year 1883: having passed undetected in the reductions made under Henderson's superintendence, and having given rise to the introduction of a supposed *η Doradus* in the catalogues of Variable Stars. (See *Astron. Nachr.* CV, p. 22.)

A singular class of errors, which cannot be explained by any supposition of error in transcription, calls for special mention; for these, although perhaps not frequent, yet occur with sufficient frequency to be clearly recognized. It consists in the record of an ingress or egress as having occurred at just that interval, after the beginning of a minute, at which it really took place before it. Thus a transit at $11^m\ 49^s$ would be noted as at $15^m\ 11^s$, one at $9^m\ 53^s$ as at $10^m\ 7^s$, etc. This may be explained by supposing that Lacaille was sometimes in the habit of beginning to count the seconds at the moment of a transit for which he was not prepared, and continuing until the second-hand of his clock arrived at the zero. At times of haste or confusion this might easily lead to the kind of error referred to.

Mistakes of 5^s are evidently not uncommon; yet of course so small an error as this ought not lightly to be taken for granted, since the ordinary inaccuracies of observation, combined with possible proper motion, might easily lead to an apparent discordance of the same order of magnitude which would result from a mistake of 5^s in one of the moments of transit. And much delicacy of judgement is requisite, in deciding whether the supposition of such an error is warrantable. Indeed it has, throughout this investigation, been a task of no small difficulty to avoid the extremes of a too great readiness, on the one hand, to suppose the existence of an error in the record, and of too great unwillingness, on the other, to suggest probable mistakes, when such supposition is not absolutely demanded. In order to escape danger from mistaken judgement the essential facts are, for the most part, stated in every case. The correctness of these suggestions is in no case urged, or even maintained, but full data are given for judging concerning them.

In a very few instances I have ventured to suggest changes in the recorded times for both ingress and egress of the same star; but only when they seem highly probable, and the record cannot otherwise be well explained.

Many of the remaining discordances may with probability be attributed to proper motion; yet when it is remembered how small was the telescope employed, how irregular were the reticules, and how largely the resultant declination often varied for a small change in the interval between ingress and egress, it is evident that the degree of accuracy to be expected is not at all comparable with that demanded from the delicate instruments and methods of recent years.

Finally it must not be forgotten that the reduction-tables employed in deducing these catalogue-places are only approximately correct. Those of HENDERSON, given in the appendix to the catalogue, have been used throughout, excepting that for the observations, already mentioned, upon p. 121 of the *Coelum Australe*.

It has been mentioned, in another place that, although no magnitudes fainter than 7^{M} were assigned by LACAILLE to any of his stars, many of them are now and probably were then fainter than 8^{M}, and some certainly not brighter than 9^{M}.

In the following list of erroneous positions, the numbers for the stars are those of the Catalogue edited by BAILY, and the places on the left are taken from this: an adjacent column giving the page of the *Coelum Australe* which contains the original observation. At the right-hand side of the page are the magnitudes and reference-numbers of the same stars taken from the *Argentine General Catalogue*, together with their positions for 1750.0 as deduced from the data in that work. To those stars for which an error was detected by MACLEAR or ARGELANDER, the initial letters of these names are prefixed.

ERRONEOUS STAR-PLACES IN LACAILLE'S CATALOGUE.

	Catalogue-position.			C. A.		Arg. Gen. Catal. for Equinox 1750.0			
	No.	R.A.	N.P.D.			No.	Mag	α	δ
		h m s	° ′ ″	page				h m s	° ′ ″
	24	0 3 42.1	110 11 37	65	Assume ingress at 23 59 35 instead of 0 2 55, which gives $0^{h}\,1^{m}\,58^{s}.3$, 51° 15′ 21″	111	8½	0 1 57.1	51 15 19
	36	0 6 4.4	141 15 3	65	Assume ingress at 0 3 12 instead of 0 3 42 which gives $0^{h}\,5^{m}\,48^{s}.7$, 51° 18′ 8″	209	7¾	0 5 54.3	51 17 41
	37	0 6 4.5	121 20 0	113	Assume ingress at 0 4 30 instead of 0 4 33, which gives $0^{h}\,6^{m}\,4^{s}.2$, 31° 20′ 28″	215	8	0 6 3.6	31 20 50
	49	0 8 21.8	121 3 35	113	Assume ingress at 0 7 23 instead of 0 7 28, which gives $0^{h}\,8^{m}\,19^{s}.3$, 31° 4′ 39″	218	8	0 8 19.5	31 4 36
	45	0 7 23.1	111 52 16	65	Assume ingress at 0 4 47 instead of 0 5 7, which gives $0^{h}\,7^{m}\,13^{s}.5$, 51° 49′ 5″	231	7¼	0 7 10.8	51 19 10
	95	0 15 34.6	146 6 27	53	Assume ingress at 0 15 7 instead of 0 14 7, which gives $0^{h}\,16^{m}\,5^{s}.2$, 55° 58′ 12″; and if egress was exchanged with that of 102, then $0^{h}\,16^{m}\,12^{s}.1$, 56° 0′ 8″	388	7½	0 16 11 3	56 0 34
	102	0 16 47.9	145 50 27	53	Assume egress at 0 18 8 instead of 0 18 22, being exchanged with that of 95, which gives $0^{h}\,16^{m}\,41^{s}$, 55° 48′ 30″	399	7½	0 16 40.2	55 49 0
M	139	0 22 40.6	162 37 15	19	Assume ingress at 0 20 25 instead of 0 20 35, which gives $0^{h}\,22^{m}\,35^{s}.5$, 72° 38′ 41″ (*θ Tucanae*)	191	6½	0 22 38.1	72 38 53
A	147	0 24 28.2	116 8 4	127 131	Wrongly reduced $0^{h}\,24^{m}\,28^{s}.2$, 26° 8′ 20″ $28^{s}.2$, 24	541	6 large proper motion	0 24 41.4	26 8 18
	209	0 34 17.1	165 30 22	15	Assume egress at 0 36 50 instead of 0 35 50, which gives $0^{h}\,34^{m}\,46^{s}.3$, 75° 37′ 28″	690	8	0 34 49.7	75 38 9
	222	0 36 51.6	141 48 39	59	Assume egress at 0 41 25 instead of 0 40 15, which gives $0^{h}\,37^{m}\,12^{s}.0$, 54° 42′ 43″	711	7¼	0 37 10.1	51 12 2
	227	0 37 26.2	127 49 6	101	Assume egress at 0 42 54 instead of 0 43 54 which gives $0^{h}\,36^{m}\,57^{s}.4$, 37° 37′ 19″	712	7½	0 36 59.8	37 37 56
	248	0 42 31.9	177 12 0	1	Wrongly reduced $0^{h}\,42^{m}\,32^{s}$, 87° 5′ 30″	700	7	0 41 56.0	87 4 20
	260	0 44 54.1	179 15 28	1	*α Octantis.* Ingress should be 15^{m} and egress 10^{m} earlier	222	7¼	0 33 0.0	89 15 10
	292	0 52 8.0	164 13 22	19	Assume egress at 0 55 38 instead of 0 54 38, which gives $0^{h}\,52^{m}\,39^{s}.6$, 74° 4′ 42″	960	8	0 52 39.5	74 2 51
	302	0 53 51.3	131 39 35	95	Assume ingress at 0 54 55 instead of 0 55 8, which gives $0^{h}\,53^{m}\,48^{s}.0$, 41° 37′ 9″	1003	7	0 53 48 7	41 36 55
	309	0 55 0.0	131 14 35	95	Assume ingress at 0 54 52 instead of 0 55 5, which gives $0^{h}\,54^{m}\,53^{s}.8$, 41° 12′ 6″	1026	7	0 54 54 3	41 12 3
A	319	0 57 18.0	117 26 8	127	Assume ingress at 0 55 46 instead of 0 55 21, which gives $0^{h}\,58^{m}\,0^{s}.2$, 27° 31′ 13″	1081	7¼	0 58 2 1	27 31 55
	347	1 5 19.9	134 8 53	81	Assume the observation to have been in the lower part, which gives $1^{h}\,5^{m}\,27^{s}.9$, 12° 30′ 2″	1201	7¼	1 5 25 1	12 30 24
	349	1 5 31.2	161 11 1	19	There is a misprint of 71 for 72 in English edition. Assume ingress at 1 4 38 instead of 1 4 48, which gives $1^{h}\,5^{m}\,26^{s}$, 72° 12′ 32″	1171	8½	1 5 25 5	72 12 10
	370	1 10 32.3	124 21 23	107	Assume ingress at 1 6 41 instead of 1 7 41 which gives $1^{h}\,10^{m}\,1^{s}.5$, 34° 33′ 36″	1287	7	1 10 3.6	34 33 0
	379	1 11 24.1	126 9 19	107	Interchanging the times of egress, we have $1^{h}\,10^{m}\,58^{s}.0$, 35° 58′ 50″	1305	7¼	1 10 57.6	35 58 19
	390	1 12 15.1	125 15 57	107	1 13 11.3, 35 27 10	1344	6½	1 13 9.8	35 27 7

	Catalogue-position.			C. A.		Arg. Gen. Catal. for Equinox 1750.0			
	No.	R.A.	N.P.D.			No.	Mag	α	δ
		h m s	° ′ ″	page				h m s	° ′ ″
	385	1 12 5.5	121 12 13	107	Assume ingress at 1 7 38 instead of 1 8 23, which gives $1^{h}\ 11^{m}\ 12^{s}.3$, 34° 51′ 49″	1317	6¾	1 11 11.1	31 51 42
	424	1 17 52.3	140 19 0	65	Assume egress at 1 19 34 instead of 1 19 36, which gives $1^{h}\ 17^{m}\ 51^{s}.3$, 50° 18′ 41″	1115	7	1 17 50.2	50 18 29
	426	1 18 2.7	140 15 11	65	This star does not exist: its place having been formed by combining the ingress of no. 445 with the egress of 424. These moments appear to be correctly recorded here in the wrong place, although erroneously given in the right one.				
	445	1 21 21.3	141 1 21	65	Assume ingress at 1 18 45 instead of 1 19 35, which gives $1^{h}\ 20^{m}\ 58^{s}.4$, 51° 12′ 2″, being the place of Br. 217	1465	7	1 20 57.8	51 11 18
A	433	1 19 40.0	121 21 53	113	Interchanging the times of ingress, we have $1^{h}\ 19^{m}\ 52^{s}.3$, 31° 16′ 48″	1457	6¾	1 19 53.1	31 16 56
A	437	1 20 20.6	121 29 5	113	1 20 8.4, 31 34 13	1461	6	1 20 8.6	31 34 36
A	452	1 22 33.2	118 37 23	121	Assume egress at 1 23 1 instead of 1 22 53, which gives $1^{h}\ 22^{m}\ 37^{s}.1$, 28° 39′ 8″	1514	8¼	1 22 37.0	28 39 15
A	453	1 22 12.0	119 29 47	121	Assume egress at 1 25 13 instead of 1 25 5, which gives $1^{h}\ 22^{m}\ 45^{s}.9$, 29° 31′ 29″	1518	7	1 22 45.0	29 31 33
	493	1 29 58.3	147 45 50	53	Assume ingress at 1 27 47 instead of 1 28 13, which gives $1^{h}\ 29^{m}\ 45^{s}.7$, 57° 42′ 17″	1620	7	1 29 41.8	57 42 16
A	589	1 47 32.3	117 31 13	127	Assume ingress at 1 45 57 instead of 1 45 17, which, gives $1^{h}\ 47^{m}\ 51^{s}.8$, 27° 40′ 10″	1956	6½	1 47 51.9	27 39 28
A	611	1 51 51.3	114 52 29	133	Assume egress at 1 52 21 instead of 1 53 21, which gives $1^{h}\ 51^{m}\ 20^{s}.2$, 25° 6′ 11″	2027	6½	1 51 18.5	25 6 1
A	562	1 43 41.5	116 1 34	127	Interchanging the times of egress, we have $1^{h}\ 43^{m}\ 30^{s}.3$, 26° 6′ 29″; $1^{h}\ 45^{m}\ 30^{s}.2$, 26° 50′ 19″	1873	7	1 43 29.4	26 7 39
A	570	1 45 18.9	116 55 39		Assume ingress of former at 1 41 49 instead of 1 41 54 which gives $1^{h}\ 43^{m}\ 27^{s}.8$, 26° 7′ 36″	1907	7¼	1 45 28.5	26 51 7
A	639	1 57 35.9	114 9 22	133	Assume ingress at 1 54 21 instead of 1 54 29, which gives $1^{h}\ 57^{m}\ 31^{s}.8$, 24° 11′ 10″	2150	7¼	1 57 31.2	24 11 9
M	619	1 53 26.9	144 24 5	59	Assume egress at 1 59 39 instead of 1 58 39, which gives $1^{h}\ 53^{m}\ 57^{s}.8$, 54° 14′ 59″	2060	7¼	1 53 54.6	54 14 50
M	634	1 56 19.2	175 48 11	1	Assume ingress at 1 47 20 instead of 1 48 20, which gives $1^{h}\ 55^{m}\ 49^{s}.4$, 86° 2′ 32″	1800	6	1 55 36.4	86 0 53
	645	1 58 24.9	127 8 54	101	The moment of egress for this and for the following star should apparently be 2 2 28 instead of 2 3 6	2151	7½	1 58 7.0	37 1 10
	646	1 58 33.7	127 5 33	101	Assume ingress at 1 59 40 instead of 1 59 46, which gives $1^{h}\ 58^{m}\ 12^{s}.3$, 36° 59′ 14″	2158	8	1 58 12.1	36 59 17
A	672	2 2 14.0	114 29 21	133	Assume ingress at 1 58 50 and egress at 2 3 57 for reasons given by ARGELANDER BB. VII. 243. This gives $2^{h}\ 1^{m}\ 43^{s}.8$, 24° 3′ 17″	2239	7½	2 1 12.3	24 3 15
	683	2 4 19.4	127 23 48	101	Assuming egress at 2 11 30 instead of 2 10 10, we obtain $2^{h}\ 5^{m}\ 27^{s}.9$, 37° 39′ 23″; and if ingress were at 2 5 22 instead of 2 5 17, we should have $2^{h}\ 5^{m}\ 30^{s}.4$, 37° 38′ 25″	2311	7¾	2 5 29.7	37 38 23
A	694	2 7 35.1	115 14 34	133	Assuming ingress at 2 4 17 instead of 2 6 17, an error like that of nos. 672 and 696, we have $2^{h}\ 6^{m}\ 37^{s}.2$, 24° 47′ 13″	2313	7¼	2 7 36.6	24 47 39
A	696	2 7 50.2	113 15 57	133	Assuming at ingress the same error of 2^{m} as for nos. 672 and 692, and also the seconds as 27 instead of 37, we have $2^{h}\ 6^{m}\ 40^{s}.9$, 23° 45′ 36″	2316	8¼	2 6 13.1	23 45 10
					But if we assume both the ingress and egress to have been recorded 1^{m} too early we shall find $2^{h}\ 8^{m}\ 50^{s}.8$, 23° 15′ 58″, and thus nearly the place of G.C. 2388. The former seems to me more probable. See ARGELANDER, Bonn Obs. VII. 243.	2388	8	2 8 54.1	23 16 10
A	699	2 8 46.2	114 53 49	133	Assuming ingress at 2 6 36 instead of 2 6 41, and also egress at 2 9 33 instead of 2 10 13, we obtain $2^{h}\ 8^{m}\ 23^{s}$, 25° 1′ 50″	2375	8½	2 8 25.4	25 1 40
					But assuming ingress at 2 6 11, and leaving egress unchanged, we should have $2^{h}\ 8^{m}\ 31^{s}.7$, 24° 46′ 59″	Z.C.372	8½	2 8 28.9	24 47 39
	740	2 15 37.0	145 37 21	52	Assume ingress at 2 15 25 instead of 2 15 50, which gives $2^{h}\ 15^{m}\ 24^{s}.2$, 55° 40′ 56″	2497	7½	2 15 24.2	55 41 9

Catalogue-position.				C. A.		Arg. Gen. Catal. for Equinox 1750			
	No.	R.A.	N.P.D.			No.	Mag	α	δ
		h m s	° ′ ″	page				h m s	° ′ ″
A	744	2 17 8.6	117 35 52	127	Assume ingress at 2 14 59 instead of 2 15 4, which gives $2^h\,17^m\,6^s.1$, 27° 34′ 15″	2563	7¼	2 17 6.7	27 33 17
	759	2 18 13.5	131 38 24	95	Assume egress at 2 22 19 instead of 2 21 54, which gives $2^h\,18^m\,56^s.5$, 41° 33′ 44″	2595	7½	2 18 55.4	41 33 13
	829	2 30 44.5	145 47 12	52	Assume egress at 2 33 5 instead of 2 32 5, which gives $2^h\,31^m\,13^s.9$, 55° 55′ 32″	2811	7¾	2 31 11.2	55 55 21
A	843	2 32 31.6	119 10 11	121	Assume ingress at 2 29 48 instead of 2 28 48, which gives $2^h\,33^m\,1^s.7$, 29° 53′ 26″	2901	8	2 32 59.4	29 52 48
	881	2 37 28.0	122 23 41	113	Assume ingress at 2 33 57 instead of 2 33 37, which gives $2^h\,37^m\,37^s.8$, 32° 27′ 59″	2993	7½	2 37 36.9	32 28 33
	882	2 37 39.2	162 29 35	19	The R.A. should be printed $2^h\,39^m\,39^s.2$ instead of 2 37 39.2	2942	8	2 39 38.0	72 31 32
	884	2 37 56.7	137 24 17	77	Reduction 2^m wrong. The observations give $2^h\,39^m\,57^s.0$, 47° 23′ 6″. If egress be assumed at 2 43 8 instead of 2 43 3 we shall have $2^h\,39^m\,59^s.3$, 47° 23′ 56″	3018	7¼	2 39 58.6	47 23 48
A	924	2 44 34.0	120 10 57	121	Assume egress at 2 44 3 instead of 2 45 3, which gives (after correcting HENDERSON's table according to ARGELANDER's determination. B.B.VII. 6, $2^h\,43^m\,59^s.6$, 30° 53′ 8″	3149	8	2 44 0.8	30 52 20
M	956	2 49 11.8	154 8 3	35	Assume egress at 2 59 32 instead of 2 50 32, which gives $2^h\,51^m\,7^s.3$, 65° 3′ 58″, or ζ *Horologii*.	3279	5	2 54 8.7	65 1 17
M	961	2 50 23.5	154 54 2	35	Assume ingress at 2 43 34 instead of 2 44 34, which gives $2^h\,49^m\,52^s.9$, 65° 1′ 3″	3198	7	2 49 56.2	65 1 22
	977	2 55 12.4	146 1 27	52	Assume ingress at 2 54 30 instead of 2 54 0 which gives $2^h\,55^m\,27^s.9$, 55° 57′ 19″	3317	8	2 55 28.6	55 57 27
	1018	3 4 5.3	129 51 30	95	Assume ingress at 3 4 54 instead of 3 4 20, which gives $3^h\,4^m\,23^s.0$, 39° 45′ 5″. There is no other reason for this change than that accordance is thus attained. The proper motion is not large.	3509	7	3 4 23.3	39 45 9
A	1026	3 4 58.4	119 22 47	121	The ingress must be taken as 3 4 50 instead of 3 4 55, and egress at 3 6 35 instead of 3 7 5. See Bonn Obs. VII. 240. Then we have $3^h\,4^m\,41^s.1$, 29° 17′ 25″	3528	7½	3 4 40.8	29 17 10
	1030	3 5 26.6	131 24 56	95	Assume ingress at 3 4 50 instead of 3 6 0, which gives $3^h\,4^m\,53^s.1$, 41° 11′ 35″	3518	7½	3 4 54.8	41 11 56
	1050	3 7 9.3	141 39 11	64	Declination should be 51° 29′ 11″, a typographical error.				
	1076	3 12 51.2	175 11 51	1	The moments here seem clearly wrong, but to bring them into accord with the present position would require the subtraction of $1^m\,45^s$ from the ingress, and also 30^s from the egress. This would give $3^h\,11^m\,44^s.6$, 86° 2′ 56″	3172	7¼	3 11 13	86 2 10
	1097	3 16 1.4	156 19 43	29	Assume egress at 3 16 18 instead of 3 16 38, which gives $3^h\,15^m\,51^s.6$, 66° 47′ 45″	3665	7¼	3 15 51.2	66 47 35
	1098	3 16 3.4	156 39 52	37	Assume ingress at 3 14 59 instead of 3 15 14, which gives $3^h\,15^m\,55^s.9$, 66° 38′ 11	3670	7¼	3 15 57.0	66 38 6
A	1102	3 16 16.8	119 25 7	121	Substitute 3 18 25, the recorded ingress of L. 1121 for 3 18 29, the recorded egress of this star. Then we have $3^h\,16^m\,19^s.7$, 29° 26′ 25″	3755	7¼	3 16 18.7	29 26 58
M	1116	3 19 10.7	131 14 12	85	Assume egress at 3 26 27 instead of 3 22 27 which gives $3^h\,21^m\,16^s.0$, 43° 30′ 8″	3840	6	3 21 11.8	43 30 12
	1119	3 19 19.7	142 57 19	58	Assume ingress at 3 17 37 instead of 3 19 39, which gives $3^h\,18^m\,17^s.0$, 53° 15′ 58″	3759	8½	3 18 16.7	53 16 7
A	1121	3 20 15.4	118 46 10	121	Substitute 3 18 29, recorded egress of L. 1102, for 3 18 35, recorded ingress of this star and we have $3^h\,20^m\,12^s.4$, 28° 47′ 28″	3837	7	3 20 12.6	28 47 13
	1123	3 20 58.3	129 18 21	95	Assume ingress at 3 21 56 instead of 3 22 56, which gives $3^h\,20^m\,37^s.5$, 39° 26′ 5″	3835	8	3 20 55.8	39 25 41
	1148	3 25 51.8	150 50 36	17	Assume egress at 3 26 32 instead of 3 25 12 and we have $3^h\,26^m\,20^s.3$, 60° 44′ 26″, or another observation of Lac. 1149 already observed on p. 49	3911	7	3 26 19.4	60 42 57
	1151	3 26 52.9	151 9 15	13	These observations are reduced in the British edition using 3 27 14 instead of 3 37 14 for time of egress. But it is necessary to assume the ingress at 3 25 59 instead of 3 26 22, which gives $3^h\,31^m\,31^s.3$, 62° 22′ 10	4025	7¼	3 31 35.8	62 22 27

Catalogue-position.			C. A.		Arg. Gen. Catal. for Equinox 1750.0			
No.	R.A.	N.P.D.			No.	Mag	α	δ
	h m s	° ′ ″	page				h m s	° ′ ″
1168	3 29 7.1	148 46 58	17	Assume ingress at 3 26 13 instead of 3 25 43, which gives $3^h\,29^m\,3^s$, 58° 39′ 17″, being another observation of Lac. 1170, also observed on p. 49.	3997	7½	3 29 31.0	58 38 55
1173	3 29 51.2	143 16 35	58	Assume egress at 3 34 49 instead of 3 33 54, which gives $3^h\,30^m\,17^s.9$, 53° 54′ 26″	4024	7¾	3 30 17.8	53 54 29
1192	3 32 27.0	148 6 40	52	Assume ingress at 3 31 54 instead of 3 31 59, which gives $3^h\,32^m\,24^s.5$, 58° 6′ 0″	4053	7¼	3 32 21.0	58 6 28
1193	3 32 39.7	146 55 15	52	Assume ingress at 3 27 50 instead of 3 28 10, which gives $3^h\,32^m\,29^s.5$, 56° 57′ 47″	4059	7¾	3 32 32.3	56 57 53
1200	3 33 13.1	146 52 22	52	Assume ingress as recorded for no. 1201, 3 29 20, and reduce for *upper* part, which gives $3^h\,33^m\,42^s.9$, 57° 3′ 14″	4084	7	3 33 42.8	57 3 2
1201	3 33 46.9	146 51 28	52	Assume ingress as recorded for no. 1200, deducting 20^s making 3 29 4, which gives $3^h\,33^m\,43^s.7$, 56° 57′ 49″	4087	7¾	3 33 43.3	56 57 48
1209	3 34 26.8	147 31 34	53	The star observed seems to have been G.C. 4107, but its position can be reproduced only by supposing the ingress to have been 30^s earlier and the egress 40^s later than recorded. These changes would give $3^h\,34^m\,32^s.5$, 57° 21′ 50″	4107	8	3 34 35.1	57 21 53
M 1210	3 34 38.4	178 7 50	11	Assume egress at 3 45 37 instead of 3 35 47, which gives $3^h\,39^m\,49^s.4$, 79° 9′ 55″	4010	6	3 39 50.6	79 10 28
1233	3 37 32.6	145 8 46	59	Assume ingress at 3 37 28 instead of 3 36 38, which gives $3^h\,37^m\,57^s.8$, 55° 16′ 2″	4176	7	3 37 58.3	55 16 30
1251	3 40 15.7	121 22 44	113	Using ingress 3 38 45 of no. 1252, we have $3^h\,40^m\,35^s.5$, 31° 27′ 23″	4275	7¼	3 40 34.6	31 27 36
1252	3 41 10.1	121 42 49	113	Using ingress 3 39 7 as recorded for no. 1251, we have $3^h\,41^m\,21^s.5$, 31° 38′ 11″	4299	7	3 41 22.1	31 38 24
1276	3 44 18.0	135 47 29	77	Assume ingress at 3 44 18 instead of 3 43 43, which gives $3^h\,44^m\,36^s.5$, 45° 41′ 32″	4341	7¾	3 44 36.0	45 42 5
1290	3 46 1.1	137 34 47	71	Assume ingress at 3 46 39 instead of 3 46 49, which gives $3^h\,45^m\,51^s.1$, 47° 38′ 8″	4364	8½	3 45 50.0	47 37 15
1295	3 46 46.0	164 39 15	19	Assume ingress at 3 46 7 instead of 3 45 7, which gives $3^h\,47^m\,14^s.7$, 74° 47′ 19″	4264	7½	3 47 12.5	74 46 55
1298	3 46 58.5	162 42 18	19	Assume ingress at 3 45 26 instead of 3 44 26, and egress at 3 47 13 instead 3 48 13, which gives $3^h\,47^m\,0^s.6$, 72° 24′ 44″	4289	6½	3 46 55.3	72 25 41
1300	3 47 32.6	145 33 1	59	Assume egress at 3 48 35 instead of 3 48 55, which gives $3^h\,47^m\,22^s.2$, 55° 35′ 52″	4375	7¾	3 47 20.9	55 35 19
1303	3 47 58.5	145 33 3	52	This star is manifestly identical with no. 1300, there being no other in the sky which could have been noted as this was. Yet the observations can only be made conformable by supposing errors of record in both ingress and egress. Assuming the former as 45^s and the latter 25^s earlier, we should have for the observations 3 47 40 and 3 48 2, which give the position $3^h\,47^m\,23^s.2$, 55° 35′ 52″				
1315	3 50 25.2	133 4 6	84	Assume ingress at 3 49 20 instead of 3 49 0, which gives $3^h\,50^m\,35^s.6$, 43° 0′ 31″	4450	7¾	3 50 37.4	43 0 26
1334	3 54 1.8	167 33 4	15	Assume egress at 3 54 18 instead of 3 53 48, which gives $3^h\,54^m\,17^s.5$, 77° 28′ 31″	4371	8	3 51 16.3	77 27 48
1361	3 58 1.1	141 52 26	65	Assume ingress at 3 57 2 instead of 3 55 47, which gives $3^h\,58^m\,40^s.1$, 52° 4′ 19″	4605	8	3 58 10.0	52 3 39
A 1368	3 58 57.0	119 33 19	121	Assume ingress at 3 55 20 instead of 3 55 28, which gives $3^h\,58^m\,52^s.9$, 29° 35′ 32″	4636	7¾	3 58 53.0	29 35 1
M 1392	4 1 42.5	154 54 49	37	Assume ingress at 3 59 7 instead of 3 58 57, which gives $4^h\,4^m\,47^s.5$, 64° 53′ 48″	4674	6½	4 4 47.1	64 53 53
A 1393	4 4 52.0	113 58 57	133	Assume ingress at 4 2 37 instead of 4 2 7, which gives $4^h\,5^m\,7^s.5$, 23° 52′ 10″	4772	6¾	4 5 7.3	23 52 47
1427	4 11 48.1	143 35 58	58	Wrongly reduced in British edition, owing to misplacement of a type in the original. Ingress was at 4 10 41, which gives $4^h\,12^m\,8^s.4$, 53° 30′ 8″	4857	7	4 12 7.5	53 31 11
1446	4 15 43.5	130 32 25	95	Observation must have been in the upper part. Reducing accordingly, and assuming egress at 4 21 23 instead of 4 21 28, we obtain $4^h\,15^m\,44^s.0$, 40° 38′ 51″	4952	7½	4 15 42.2	40 38 32

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No.	R.A.	N.P.D.			No.	Mag	α	δ
	h m s	° ′ ″	page				h m s	° ′ ″
A 1450	4 16 27.9	120 57 22	121	Assume ingress at 4 15 40 instead of 4 15 45 and egress at 4 16 24 instead of 4 16 19, which gives 4h 16m 24s.1, 30° 54′ 28″	4972	7¼	4 16 23.5	30 54 17
A 1459	4 17 36.3	119 49 12	121	Assume ingress at 4 14 5 instead of 4 14 15, which gives 4h 17m 31s.0, 29° 46′ 41″	4999	8	4 17 30.2	29 46 32
1467	4 18 13.5	142 22 16	65	Assume ingress at 4 19 0 instead of 4 8 5, which gives 4h 19m 9s.9, 52° 30′ 17″	4995	7¼	4 19 9.1	52 30 42
A 1468	4 18 49.1	120 22 20	121	Assume ingress at 4 16 34 instead of 4 16 41 which gives 4h 18m 42s.4, 30° 19′ 23″	5021	7½	4 18 43.2	30 19 33
A 1480	4 19 49.9	119 35 4	121	Assume ingress at 4 16 13 instead of 4 16 18, which gives 4h 19m 47s.4, 29° 36′ 7″	5044	8	4 19 17.3	29 35 28
A 1485	4 20 2.3	119 26 4	121	The best accordance may be obtained by assuming the ingress at 4 16 49 instead of 4 16 51 which gives 4h 20m 1s.3, 29° 26′ 28″	5050	7¾	4 20 0.1	29 26 27
A 1491	4 21 26.4	119 25 37	121	Assume ingress at 4 18 11 instead of 4 18 16, which gives 4h 21m 23s.8, 29° 26′ 41″	5082	7½	4 21 23.5	29 26 7
1493	4 21 31.4	129 27 31	95	Assume ingress at 4 21 46 instead of 4 22 46, which gives 4h 21m 0s.2, 39° 39′ 1″	5056	7½	4 21 1.0	39 38 56
1497	4 21 35.1	126 12 11	95	Assume ingress at 4 22 40 instead of 4 23 10, which gives 4h 21m 37s.4, 39° 32′ 20″	5073	7½	4 21 35.9	39 32 18
A 1501	4 22 24.4	115 46 3	127	Error of reduction in British edition. Also assume ingress at 4 21 27 instead of 4 21 32, which gives 4h 22m 17s.0, 25° 44′ 55″	5115	8¾	4 22 16.0	25 45 10
1542	4 29 1.8	151 43 11	13	This and five following stars are recorded in the *Coelum Australe* one hour too early, 1751 Dec. 16. The hour should be 5, giving position 5h 29m 1s.8, 61° 43′ 7″	6506	7½	5 29 1.9	61 43 17
1546	4 30 24.7	145 30 32	59	Assume ingress at 4 30 8 instead of 4 30 48, which gives 4h 30m 5s.3, 55° 24′ 50″	5233	7½	4 30 5.2	55 21 38
1554	4 32 18.1	151 20 25	13	Assuming the hour as 5 instead of 4, we have 5h 32m 18s.1 61° 20′ 17″	6589	6¾	5 32 14.9	61 20 7
1562	4 33 26.1	135 11 31	77	Assume ingress at 4 33 39 instead of 4 32 59, and egress at 4 40 19 instead of 4 39 19, which gives 4h 34m 15s.5, 45° 47′ 54″	5320	7½	4 34 17.7	45 47 13
A 1570	4 34 25.9	118 27 52	121	Assume ingress at 4 33 36 instead of 4 33 26, which gives 4h 34m 30s.9, 28° 25′ 41″	5347	7¼	4 34 29.3	28 25 12
1593	4 37 15.1	140 18 16	65	Assume ingress at 4 37 21 instead of 4 37 44 which gives 4h 37m 5s.8, 50° 21′ 56″	5369	7½	4 37 6.3	50 21 46
1602	4 38 12.6	141 35 4	65	Can only be made accordant with the sky by supposing both ingress and egress recorded too late, the former by 30s and the latter by 20s. Assuming the true times as 4 34 29 and 4 43 27 we have 4h 37m 17s.8, 51° 33′ 27″	5381	8½	4 37 18.1	51 33 22
1633	4 43 28.2	151 18 44	13	The hour should be 5. Then assume ingress at 5 41 23 instead of 5 41 33, which gives 5h 43m 23s.1, 61° 19′ 48″	6856	7½	5 43 21.9	61 19 26
1661	4 47 51.0	129 16 53	95	Assume ingress at 4 49 12 instead of 4 49 32, which gives 4h 47m 40s.5, 39° 20′ 45″	5635	7½	4 47 11.5	39 20 50
A 1665	4 48 31.6	119 9 2	121	Assume egress at 4 50 15, recorded for no 1673, which gives 4h 48m 50s.8, 29° 17′ 23″; both ingress and egress requiring a correction of 8s	5678	7¼	4 48 13.1	29 17 7
A 1673	4 49 36.1	118 58 9	121	Using the egress 4 50 6, recorded for no 1665, we obtain 4h 49m 17s.0, 28° 49′ 11″	5690	7¼	4 49 15.6	28 50 9
1680	4 50 50.1	151 53 31	13	The hour should be 5, giving 5h 50m 50s.5, 61° 53′ 21″	7031	7	5 50 51.1	61 53 16
1691	4 52 44.8	144 23 14	59	Assume ingress at 4 50 12 instead of 4 49 12, which gives 4h 53m 44s.9, 54° 30′ 47″. Supposing also the egress at 4 57 52 instead of 4 57 57, we should have 4h 53m 12s.3, 54° 33′ 2″	5732	7¼	4 53 12.1	54 33 11
1706	4 53 39.9	151 28 10	13	The hour should be 5, the corresponding place being 5h 53m 39s.7, 61° 28′ 3″. Assuming ingress at 5 50 55 instead of 5 51 5, we obtain the position 5h 53m 34s.7 61° 29′ 13″	7108	8	5 53 33.7	61 28 50
1723	4 57 31.5	162 17 17	19	Assume ingress at 4 54 29 instead of 4 54 39, which gives 4h 57m 26s.5, 72° 18′ 42″; the same star as Lac. 1721	5719	6¾	4 57 21.0	72 18 21
1734	4 59 57.1	145 46 41	52	Assume ingress at 4 59 5 instead of 4 59 35, which gives 4h 59m 42s.1, 55° 50′ 52″	5861	8	4 59 17.0	55 50 58

Catalogue-position. No.	R.A.	N.P.D.	C. A.		Arg. Gen. Catal. for Equinox 1750.0 No.	Mag	α	δ
	h m s	° ′ ″	page				h m s	° ′ ″
1712	5 1 4.5	148 7 12	53	Assume ingress at 4 59 40 instead of 5 0 40, which gives $5^h\,0^m\,35^s.4$, 57° 59′ 40″	5879	7½	5 0 37.3	58 1 3
1715	5 1 23.9	131 5 16	95	Assume egress at 5 6 57 instead of 5 5 57, which gives $5^h\,1^m\,55^s.0$, 40° 53′ 42″	5956	7½	5 1 54.0	10 53 7
1766	5 1 14.3	152 6 57	43	Should be one hour later, giving $6^h\,4^m\,14^s.2$, 62° 6′ 48″ The imaginary *μ Doradus*.	7410	5¾	6 1 17.0	62 6 59
1790	5 7 59.4	131 27 13	95	By supposing the ingress 23^s later, *i.e.* 5 9 4 instead of 5 8 41, we obtain $5^h\,8^m\,10^s.4$, 41° 32′ 5″	6080	7½	5 8 10.0	41 32 17
1805	5 10 35.3	131 23 44	95	Supposing ingress 23^s earlier, *i.e.* 5 10 43 instead of 5 11 6, we obtain $5^h\,10^m\,24^s.3$, 41° 19′ 22″	6129	7	5 10 25.1	41 19 7
1818	5 12 51.5	155 35 11	37	Assume ingress at 5 6 10, instead of 5 6 50, which gives $5^h\,12^m\,31^s.5$, 65° 30′ 49″	6097	7¾	5 12 31.2	65 31 13
1819	5 12 59.5	173 49 58	3	Assuming ingress at 5 3 35 instead of 5 4 35, we have $5^h\,12^m\,28^s.3$, 83° 52′ 53″: a second observation of Lac. 1816.	5685	7	5 12 30.5	80 53 40
1832	5 14 51.1	121 45 46	107	Assume ingress at 5 11 30 instead of 5 11 0, which gives $5^h\,15^m\,7^s.5$, 34° 39′ 41″	6254	7¾	5 15 6.3	34 39 41
1846	5 17 2.6	126 55 29	101	Assume egress at 5 20 9 instead of 5 21 9, which gives $5^h\,16^m\,33^s.7$, 36° 43′ 35″	6290	7¾	5 16 33.7	36 43 54
1847	5 17 6.6	141 29 6	64	Reducing for upper part of the reticule, we obtain $5^h\,17^m\,10^s.3$, 51° 34′ 49″	6270	7½	5 17 9.2	51 33 27
1856	5 18 33.9	126 36 35	101	Assume ingress at 5 19 55 instead of 5 20 55, which gives $5^h\,18^m\,2^s.8$, 36° 48′ 33″. This error of 1^m occurs for four successive stars on p. 65, *inf.*	6324	7¾	5 18 2.7	36 48 46
1864	5 19 22.4	135 11 43	77	Can be reconciled with the sky by assuming ingress 5 20 15 instead of 5 20 25, and supposing egress at 53^s instead of 35^s. This gives $5^h\,19^m\,25^s.6$, 45° 16′ 32″	6347	8	5 19 26.5	45 16 31
1891	5 21 14.8	120 3 10	121	Adopting **Argelander**'s suggestion, and interchanging recorded egress of 1891 with ingress of 1915, we find $5^h\,24^m\,14^s.6$, 30° 1′ 58″	6476	7	5 24 14.8	30 2 12
1901	5 25 11.5	137 36 36	71	Assume ingress at 5 26 6 instead of 5 26 26, which gives $5^h\,25^m\,34^s.3$, 47° 39′ 57″	6473	7¾	5 25 34.8	47 39 52
1915	5 28 1.1	118 50 40	121	Substituting for recorded ingress, the egress of 1891, we find $5^h\,28^m\,0^s.4$, 28° 51′ 6″	6574	5¼	5 27 59.4	28 51 20
1953	5 32 6.1	165 11 52	17	To make this accord with any known star we must suppose both moments to have been recorded too late, the ingress by $1^m\,40^s$ and the egress by 2^m. This would then give $5^h\,30^m\,16^s.7$, 75° 12′ 21″	6115	8½	5 30 17.3	75 12 49
1958	5 32 21.6	151 7 31	19	I cannot explain this observation by any plausible suggestion.				
1961	5 32 40.3	144 49 17	59	The egresses of 1961 and 1966 have been transposed. Assuming also the ingress of this star at 5 30 29 instead of 5 30 39, we have $5^h\,32^m\,50^s.4$, 54° 41′ 1″	6610	7½	5 32 48.5	54 43 4
1966	5 33 49.2	145 1 49	59	Assume egress at 5 36 26 as recorded for 1961, which gives $5^h\,33^m\,34^s.2$, 55° 6′ 4″	6653	7¼	5 33 33.2	55 6 0
1969	5 34 32.4	135 1 23	77	Assume ingress at 5 35 48 instead of 5 36 3, which gives $5^h\,34^m\,24^s.4$, 45° 4′ 0″. The stars were passing through the field rapidly, and four of the six stars whose transits are recorded in the lower part between 5 36 3 and 5 42 6 appear to be wrong. Also the egress of no. 1944, one of the three stars recorded in the upper part, seems to require diminution by 5 seconds.	6699	7½	5 34 24.2	45 3 37
1980	5 36 18.8	135 50 53	77	Reducing for the upper part instead of the lower, we obtain $5^h\,36^m\,16^s.7$, 46° 34′ 16″	6748	7½	5 36 16.8	46 34 38
1983	5 36 43.9	146 21 57	52	Assume egress at 5 41 24 instead of 5 40 24, which gives $5^h\,37^m\,13^s.3$, 56° 33′ 1″	6738	7¾	5 37 13.5	56 33 49

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THE THEORY OF THE REFLEX ZENITH-TUBE AND DISCUSSION OF THE OBSERVATIONS OF γ *DRACONIS*.

BY CHARLES LANE POOR,

[Student at the Johns Hopkins University.]

The Reflex Zenith-Tube, designed by Sir GEORGE BIDDELL AIRY, was in continuous use for nearly thirty years in measuring the zenith distances of γ *Draconis*. As the instrument appeared so perfect, theoretically, a most accurate determination of the star's parallax and of the constant of aberration was expected. In the *Monthly Notices* of the Royal Astronomical Society for May, 1882, is a paper by Mr. DOWNING containing a discussion of the observations made during the years 1857–1875. The constant of aberration as deduced was $20''.378 \pm 0''.040$, or considerably less than the usually accepted value. The annual parallax of γ *Draconis* resulting from the observations was $-0''.131 \pm 0''.041$, a quantity which he thinks cannot be regarded as accidental. It must be assumed, according to Mr. DOWNING, that there is a periodic error of some kind, probably due to the effect of temperature on the instrument.

On the suggestion of Professor NEWCOMB I undertook last spring a rediscussion of these observations. The results were again unsatisfactory, although the constant of aberration came out a somewhat larger quantity. This led to an investigation of the theory of the instrument, special attention being directed to the systematic errors, arising from the observations being made off the meridian, from possible non-parallelism of the micrometer wires, etc. The results of this investigation form the gist of this paper.

The Reflex Zenith-Tube, as described in the Greenwich observations for 1854, consists of an objective with its axis vertical, and below this, distant nearly half the focal length, a mercury-basin. Just above, and firmly fastened to the objective, is a micrometer. Objective and micrometer together can be revolved about a vertical axis. In figure I, let o and o' be the principal points of the objective, and ao, $o'R$ be that ray from a star near the zenith, whose direction is unaltered by its passage through the lens. If the mercury basin be distant from the lens a little less than half the focal length, the image of the star will be formed at P above the lens and in the plane of the micrometer; and if K be the point in the micrometer plane vertically above the first principal point o, or, what is the same thing, the place where the image of a star in the zenith would be formed: then the distance PK will be proportional to the star's zenith-distance. Were the point K visible, this distance PK could be directly measured with the micrometer and the star's zenith-distance thus found. This being impossible, the distance PK must be found indirectly as follows. Suppose the micrometer-wire placed on the image at P, and the reading noted: now revolve the object-glass and micrometer through 180° about a vertical axis. The image of the star will now appear at P', the same distance from K as P was, but on the opposite side of K as regards the lens and micrometer. By now placing the wire on the image, we measure the distance PP', the half of which is the required distance PK.

That the two settings necessary to a complete observation may be made at one transit of the star the following arrangement of the micrometer was adopted. There are two wires at a fixed distance apart, moved by two opposite micrometer screws, by means of either of which the position of the wires may be changed without altering the reading of the other. Before an observation the readings of both heads are noted. As the star comes into the field, its image is bisected by the first wire by means of micrometer A, and the instrument at once reversed without waiting to read the micrometer. Now, by means of micrometer B, the second wire is caused to bisect the image of the star. Both heads are again read and the observation is complete. The first reading of B and the second of A give the position of the wires in the direct setting; the last two readings give their position in the reversed setting. The method of deducing the zenith-distance from such an observation will be more clearly seen by reference to figures II and III, which respectively represent the micrometers and field, as seen from above, in the direct and reversed positions of the instrument.

$a_0 b_0$ is some determinate or zero position of the wires a and b.

$a_{,}b_{,}$ and $a_{,,}b_{,,}$ are their positions where the image is bisected respectively by b and a in the direct and reversed positions of the instrument.

From the figures we have directly,

$$KP = Kb_0 + b_0 b_{,} = a_0 b_0 - a_0 K + a_0 a_{,} \qquad \text{Fig. II}$$
$$KP = Ka_0 - a_0 a_{,,} \qquad \text{Fig. III}$$

whence

$$KP = \tfrac{1}{2}[a_0 b_0 + a_0 a_{,} - a_0 a_{,,}]$$

The second member is independent of the position of K. Hence the zenith-distance of the star is proportional to half the difference of the micrometer-readings in the two positions *plus* half the distance between the two wires.

In order that the readings may give the true zenith-distance it is necessary that the principal planes of the lens and the micrometer be horizontal, and that the two readings be made when the star is on the meridian. In actual observations these conditions are never fulfilled, and corrections to the observed zenith-distances thus arise. These corrections may be divided into two classes — first, those arising from errors in the level of the principal planes and micrometer; and second, those due to the fact that the complete observation can never be made when the star is on the meridian.

Level Corrections. — Consider that the plane of the micrometer is parallel to the principal planes of the lens, but all are inclined at some small angle to the horizontal plane. First take the case where this inclination is wholly in a north and south direction. Tracing out the path of the ray through the system by means of the Gaussian theory, it can be shown very easily that this level correction consists of a number of terms, all but the first being of the second or higher orders. This first term is the only correction discussed or applied by Airy in the original reductions, and is of the form

$$\delta = \frac{d}{e}\,a$$

where,

a = inclination as shown by the spirit level.
d = distance of the micrometer above the first principal plane.
e = a constant very nearly equal to the focal length of the lens.

The instrument might also be inclined from the east towards the west, thus throwing the image off the meridian. The distance that the image would so be thrown might be found in a manner entirely similar to the above. It might amount to about $1''$ of arc. This, however, would cause only a correction of the second order in the zenith-distance. Again, the plane of the micrometer might be inclined at a small angle, a', to the principal planes of the lens, the latter being considered for the moment to be horizontal. The correction resulting can easily be found to be

$$\delta = -\tan z \times a' \times \text{a constant}$$

This is of the second order, and may be neglected.

Observations off the Meridian. — If the two settings be made when the star is on the meridian, the micrometer-reading *plus* the level correction will give the true zenith-distance. When, as is always the case, at least one of the settings is made off the meridian this is no longer true. Such a reading will be affected by two kinds of errors — the first due to the fact that the star's path is not a great circle; the second due to any errors in adjustment of the micrometer. These will be treated separately, the latter first. In other words, I shall free the observed reading from the instrumental errors, and then reduce this corrected reading to the meridian.

In figure IV we have

K, the principal point of the lens.
TMK, the meridian.
A, the azimuth of the star.
ST, the apparent path of the star.
SL, the micrometer wire.
β, the angle the micrometer wire makes with the prime vertical.
LK, the instrumental reading.
KM, the corrected instrumental reading.

From the triangle LSK we have

$$\tan LK = \tan SK \cos(\beta + A)$$
$$\tan SK = \frac{\tan LK}{\cos(A+\beta)}$$

Again, from the triangle MSK,

$$\tan MK = \tan SK \cos A$$
$$= \frac{\cos A}{\cos(A+\beta)} \tan LK$$

Putting $MK = LK + \delta z$, and expanding we have

$$\tan LK + \tan \delta z = \frac{\cos A}{\cos(A+\beta)} \tan LK - \frac{\cos A}{\cos(A+\beta)} \tan^2 LK \tan \delta z$$

The last term may be neglected, and as both LK and δz are very small, LK at its maximum being about $2'$, we may replace the tangents by these arcs, whence we have for the correction,

$$dz = \left(\frac{\cos A}{\cos(A+\beta)} - 1\right) LK$$

As the star passes very close to the zenith, the azimuth will be considerable for even very small hour-angles, and the resulting correction large. This correction is to be applied to the instrumental zenith-distance in one position of the instrument. Two readings, however, are always made. From symmetry we can see that, if these two readings be made at the same distance on each side of the meridian, and if the wires be parallel, whether inclined to the prime vertical or not, the two corrections will cancel each other, and the total correction will be zero. The non-fulfillment of either one of these two conditions will give rise to corrections; — first, the wires being parallel, but inclined to the prime vertical, the two settings may be made at different distances from the meridian; second, wire *b* in the reversed position, may not be parallel to wire *a*, in the direct position. In the first case the correction will be the same as that deduced from the above formula for a single wire inclined to the prime vertical, the star having an hour-angle equal to one-half the difference of the hour-angles at the two settings. For an inclination of 5′ to the prime vertical, and a difference of hour-angles of 16^s, this correction will amount to 0″.17. In the second and more important case, when the wires have a mutual inclination, the correction will be the same as that deduced from the formula for a single wire having an inclination to the prime vertical equal to half the difference of the inclinations of the two wires, *a* and *b*, with an hour-angle equal to half the elapsed time between the two settings. For an interval of one minute of time between the settings, and a relative inclination of 1′ between the wires, this correction will be 0″.16. This relative inclination of the wires might arise either from a maladjustment of the wires themselves, or from imperfect reversals. The instrument was provided with stops to insure a reversal of exactly 180°. But however accurate these appliances, owing to the rapidity necessary in making two settings in such a short interval, it would seem hardly probable that errors of at least 3′ or 4′ should not be found.

Reduction to the Meridian. — This correction is entirely similar to that applied to declinations observed with the meridian-circle when the star is near the meridian. It is discussed by CHAUVENET in Vol. II, Article 199. The entire width of the field of the instrument is a little more than two minutes of time. In an extreme case, therefore, the star might be observed one minute from the meridian, which would give a correction of 0″.95. The total correction will be the mean of the corrections applied to each position of the instrument separately.

The conclusion is, that the true cause of the unsatisfactory results obtained with the instrument is to be sought in systematic errors arising from the possible non-parallelism of the micrometer wires, from imperfect reversals, and from the fact that the two settings can never both be made when the star is on the meridian.

Discussion of the Observations. — The observations were combined into groups, each group consisting of all the complete observations made during one month. The mean of each group was then found, it being assumed that this mean zenith-distance corresponded to the mean of the times. The positions of γ *Draconis* were then computed and the residuals (Observed — Computed) found for each group. Each residual was weighted proportionally to the number of observations in the group, and the mean by weights of all the residuals of the corresponding months in the different years, 1857–1882, taken. These mean residuals were weighted proportionally to the total number of observations made during the corresponding month.

RESIDUALS.

		Weight	No. of obs.
January	+0″.055	2	33
February	—0.015	2	49
March	+0.063	2	47
April	—0.868	1	20
May	—0.021	6	128
June	—0.319	10	219
July	—0.152	12	257
August	—0.091	12	237
September	+0.011	8	156
October	—0.177	1	71
November	+0.111	2	37
December	—0.072	2	26
Total number of observations			1280

These give the equations of condition

				Wt	Residuals
Jan.	-0.851π	$-0.123\,\delta a$	$-0''.055 = 0$	2	+0.097
Feb.	-0.514	-0.811	$+0.015 = 0$	2	+0.115
March	-0.058	-0.961	$-0.063 = 0$	2	—0.037
April	$+0.111$	-0.859	$+0.868 = 0$	1	+0.890
May	$+0.812$	-0.537	$+0.021 = 0$	6	—0.105
June	$+0.979$	-0.069	$+0.319 = 0$	10	+0.155
July	$+0.893$	$+0.400$	$+0.152 = 0$	12	—0.006
Aug.	$+0.586$	$+0.773$	$+0.091 = 0$	12	—0.021
Sept.	$+0.098$	$+0.961$	$-0.141 = 0$	8	—0.077
Oct	-0.387	$+0.881$	$+0.177 = 0$	1	+0.228
Nov.	-0.787	$+0.557$	$-0.111 = 0$	2	+0.013
Dec.	-0.947	$+0.081$	$+0.072 = 0$	2	+0.231

The resulting normal equations are:

$$33.0976\,\pi + 6.0882\,\delta a + 5''.7051 = 0$$
$$6.0882\,\pi + 26.3032\,\delta a + 1.1687 = 0$$

Solving

$$\pi = -0''.169 \qquad \text{weight} \quad 31.689$$
$$\delta a = -0.017 \qquad \text{"} \quad 25.183$$

This gives as the final results,

$$\text{Parallax of } \gamma \textit{ Draconis} = -0''.169 \pm 0.011$$
$$\text{Constant of aberration} = -20.4285 \pm 0.019$$

SOLAR OBSERVATIONS AT SHATTUCK OBSERVATORY.

BY EDWIN B. FROST.

I. OBSERVATIONS OF SPOTS.

1889	E.S.C.T. h m	No. Gps.	No. of Spots	No. new Groups	No. new Spots	No. Gps Faculae	Sky
July 1	11 30	1	1	0	0	0	C
4	15 30	0	0	0	0	0	C
6	12 30	0	0	0	0	0	C
8	17 0	0	0	0	0	2	C
17	17 0	2	5	2	5	–	C
18	12 10	2	7	0	1	–	C
19	11 30	2	8	0	2	–	K
21	15 55	1	1	0	0	–	C
22	14 30	1	1	0	0	–	C
23	15 0	1	1	0	0	2	C
24	14 30	1	1	0	0	–	K
25	14 0	0	0	0	0	0	C
26	10 40	1	5	1	5	1	C
Aug. 2	14 0	2	8	2	8	–	H
4	11 0	1	11	0	8	–	H
6	11 45	1	12	0	1	0	C
7	13 40	1	13	0	1	–	C
8	13 45	1	7	0	0	–	C
10	13 45	3	9	2	6	–	K
11	15 40	2	9	0	3	0	C
12	10 30	2	5	0	0	0	K
16	11 30	2	6	0	0	2	C
22	14 30	0	0	0	0	0	K
23	10 55	0	0	0	0	1	K
24	12 15	0	0	0	0	1	H
25	12 15	0	0	0	0	1	C
26	12 15	1	1	1	1	0	C
27	11 10	1	1	0	0	1	C
28	15 0	1	1	0	0	–	C
29	12 15	1	1	0	0	1	H
30	12 0	1	1	0	0	–	C
Sept. 6	10 15	1	1	0	0	2	K
8	15 0	1	1	0	0	1	K
9	16 30	0	0	0	0	0	H
12	9 0	0	0	0	0	1	K
13	9 40	0	0	0	0	0	K
15	16 20	0	0	0	0	0	C
20	14 0	0	0	0	0	0	K
21	17 0	0	0	0	0	–	K
22	15 0	0	0	0	0	0	C
23	10 50	1	1	1	1	1	C
24	10 30	1	3	0	2	1	K
25	11 25	1	3	0	1	1	C
27	14 35	1	8	0	1	0	CK
28	11 0	1	5	0	0	0	CK
29	15 20	1	6	0	1	0	C
Oct. 1	17 35	1	2	0	0	0	C
4	10 15	1	1	0	0	–	C
5	11 45	0	0	0	0	–	K
8	14 15	0	0	0	0	1	K
9	10 0	1	1	1	1	1	K
Oct. 10	12 0	1	1	0	0	–	KC
11	13 50	0	0	0	0	0	K
12	11 30	0	0	0	0	0	C
13	13 0	0	0	0	0	2	C
14	12 30	0	0	0	0	1	K
15	10 35	0	0	0	0	0	CC
16	11 25	1	2	1	2	0	C
17	10 45	1	1	0	0	0	C
18	10 0	0	0	0	0	2	C
19	10 15	0	0	0	0	2	C
21	10 0	0	0	0	0	1	K
22	11 15	0	0	0	0	1	C
23	10 5	0	0	0	0	1	C
24	13 35	0	0	0	0	0	C
25	11 45	0	0	0	0	0	K
26	16 30	0	0	0	0	1	KC
31	10 45	0	0	0	0	1	C
Nov. 1	15 20	0	0	0	0	0	C
4	10 45	0	0	0	0	2	C
5	14 0	0	0	0	0	0	K
7	11 0	0	0	0	0	0	C
8	14 30	0	0	0	0	0	KH
10	15 50	0	0	0	0	0	C
14	11 10	0	0	0	0	0	C
15	13 30	0	0	0	0	1	C
16	13 30	0	0	0	0	0	C
17	12 0	0	0	0	0	0	C
18	12 45	0	0	0	0	0	KC
26	11 45	0	0	0	0	0	C
29	9 10	0	0	0	0	2	C
30	13 40	0	0	0	0	0	C
Dec. 1	12 30	0	0	0	0	0	C
3	15 40	0	0	0	0	–	K
4	12 10	0	0	0	0	0	C
6	14 30	0	0	0	0	0	C
7	12 0	0	0	0	0	1	K
9	11 30	0	0	0	0	1	C
10	14 30	0	0	0	0	–	KK
11	15 40	0	0	0	0	–	KK
12	13 30	1	1	1	1	0	C
13	12 0	0	0	0	0	0	H
15	12 15	0	0	0	0	1	K
16	11 30	0	0	0	0	0	C
17	13 45	0	0	0	0	1	C
19	15 0	1	4	1	4	0	H
21	14 0	1	5	0	1	0	H
23	14 0	0	0	0	0	1	C
25	15 0	1	3	1	3	0	C
27	15 35	2	9	1	6	–	C
28	14 50	2	9	0	0	0	C
31	11 45	1	1	0	0	0	C
102 days		55	183	15	70	43	

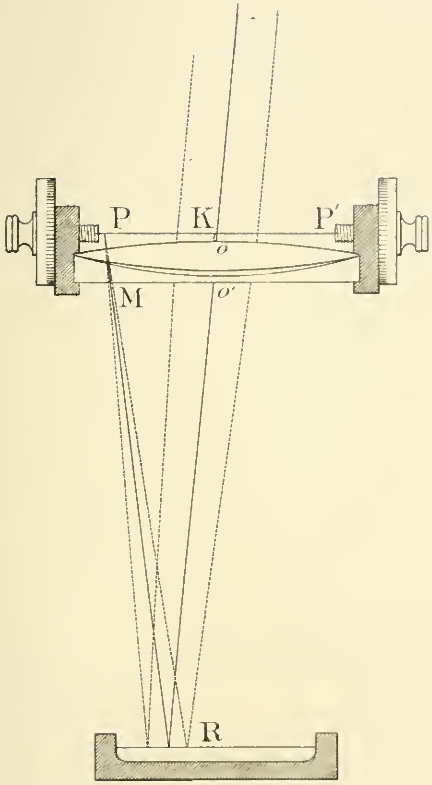
C = Clear. K = Cloudy. H = Hazy.

The above observations are in continuation of those published in no. 201 of the Journal.

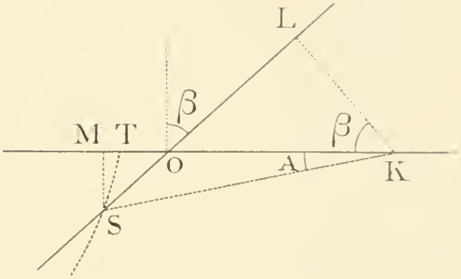
The hours are expressed in Eastern Standard Civil Time, Greenwich Time minus 5^h (reckoned from mean midnight). The obser-

Astr. Journal, No. 212.

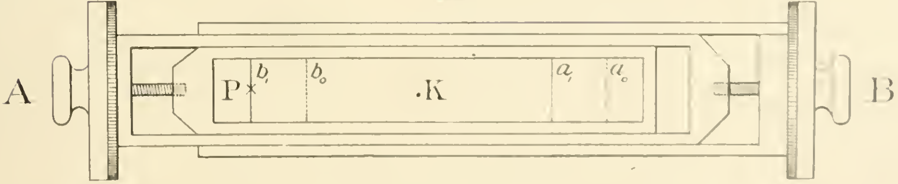
I.



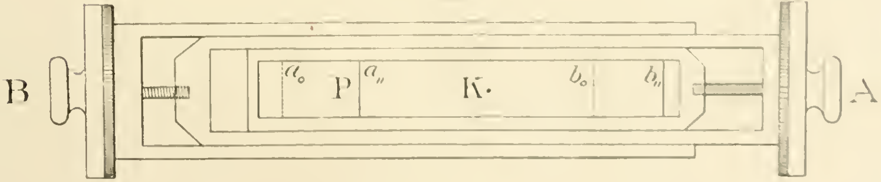
IV.



II.



III.



vations are made upon the projected image, which has a diameter of 8¼ inches, from the 9.4-inch equatorial, and an eyepiece of power 57. The term "new," as applied to groups and spots, means that the group or spot was not seen before on that rotation; deducting 3, therefore, for spots seen on more than one rotation, from the totals of new groups and new spots, we have for those totals 12 and 67. The corresponding totals of new groups and new spots for the first six months of the year are 12 and 55. The comparison shows that, on the whole, there has been hardly any increase in the spot-producing activity of the sun during the last half of the year.

In addition to the spots recorded above, I have observed very minute spot-points, hardly large enough to be classified as spots, as follows: Oct. 11, 1; 17, 3; 22, 3. Nov. 1, 1; Dec. 6, 2; 9, 4; 17, 2. One of those observed on Oct. 22 had the high latitude of about +51°. Bright faculae only have been included in the list given in the seventh column.

II. Heliographic Latitude and Longitude of the Chief Spot of Each Observed Group.

Group No.	No. of Spots in Group	1889	E.S.C.T.	b	l	Group No.	No. of Spots in Group	1889	E.S.C.T.	b	l
			h m						h m		
12	1	July 1	11 20	S 12.41	250.1	19	1	Aug. 16	11 55	S 8.21	36.6
13	4	17	17 20	S 7.55	85.9	20	1	27	11 30	S 18.97	161.6
14 = 10	1	"	"	S 8.29	35.5	20	1	28	15 0	S 18.98	161.5
13	2	18	15 10	S 7.63	87.2	20	1	30	12 0	S 19.26	160.5
14	5	"	"	S 8.35	35.3	21 = 20?	3	Sept. 21	14 5	S 20.70	151.7
14	1	22	11 55	S 8.24	36.5	21*a*	3	25	11 15	S 20.82	152.8
15	5	26	11 5	S 21.91	315.9	21*b*		"	"	S 23.31	152.6
16	4	Aug. 2	14 20	S 20.34	160.7	21*a*	8	27	15 50	S 19.58	150.6
17	4	"	"	S 1.64	201.9	21*c*		"	"	S 20.72	158.0
16*a*	11	4	14 10	S 20.38	165.3	21*a*	1	Oct. 4	10 0	S 19.71	150.8
16*b*		"	"	S 21.33	155.9	22	1	10	14 25	S 16.57	62.1
16*a*	12	6	11 30	S 19.81	166.0	23*a*	1	16	11 40	N 22.30	330.0
16*b*		"	"	S 21.10	155.6	23*b*	1	"	"	N 22.77	325.7
16*a*	3	10	14 20	S 19.93	166.5	23*b*	1	17	11 50	N 22.12	321.9
18	5	"	"	S 6.74	80.3	24	1	Dec. 12	12 0	S 6.84	333.3
19 = 14	1	"	"	S 8.34	36.7	25	4	19	14 30	N 25	165
18	4	12	12 30	S 6.93	80.7	26	6	27	14 0	S 25.71	99.8
19	1	"	"	S 8.35	36.6	27	1	31	14 0	S 8.78	313.5
18	5	16	11 55	S 6.55	81.3						

The mean latitude of the 12 southern groups is 15°.5; that of the 2 northern groups is 22°.7.

The latitudes and longitudes have been obtained by Carrington's method, except on Dec. 19, when the diagram of the projected image was measured. The factors for reduction were taken from the "Companion to the Observatory."

The southern hemisphere continues to be much more active than the northern. Group 20 is an example of a spot breaking out afresh and replaces group 16. Groups 27 and 24 are perhaps identical.

III. Spectroscopic Observations.

1889	No. of days of Observ'ns	No. of Prominences	No. of Prom. per Observ'n
July	3	9	3.0
August	5	7	1.4
September	5	11	2.2
October	11	16	1.5
November	9	17	1.9
December	11	15	1.3
	44	75	1.7

The observations in each case cover the whole circumference of the sun. Prominences less than 20″ in height are not included. Observations on 39 days, from March to June, gave almost the same number, 1.8, of prominences per observations. The prominences have been almost invariably of the quiescent type — of hydrogen, as is to be expected at a period of minimum solar activity.

The observations on August 2, 4, 16, 28–30, and December [illegible] have been made, in my absence, by Mr. J. H. Proctor.

Dartmouth College, Hanover, N.H., 1890 Jan. 30.

OBSERVATIONS OF VARIABLE STARS.

MADE AT GEORGETOWN COLLEGE OBSERVATORY.

By Rev. JOHN G. HAGEN, S.J.

The first two of the following stars were observed by myself with a 5-inch equatorial, the others by Mr. James Dawson, Professor of Physics at this College, with a 3-inch glass.

The magnitudes were reduced to the DM. scale, and the times to Greenwich M.T.

1. S *Aquarii*.

This star was observed on 22 nights, between Sept. [illegible] and Jan. 8 (1889–90). The light curve rises rapidly for 21 days from $9^M.4$ to $7^M.9$, remains almost even for [illegible] days, and then declines, with an apparent inflexion at $8^M.8$. The maximum brightness occurred about Nov. 2, 1889.

2. *R Ceti.*

The star was observed on 16 nights, between Dec. 11 and Feb. 10 (1889–90). The light-curve rises rapidly for 15 days from 9.0 to 8.2 magnitude; but there it is interrupted for 13 days. The decrease of light is slow and regular from magnitude 8.2 to 9.4. The time of maximum is, for the reason above-mentioned, doubtful within several days, but probably occurred on Jan. 3 or 4, 1890.

3. *T Ceti.*

The single observations, 36 in number, between Oct. 11 and Jan. 28 (1889–90), show great fluctuations because of the large range (10 steps) of the available comparison-stars; the light-curve, however, drawn through the middle of the plotted points, shows great regularity, without a standstill on either side of the maximum. The latter occurred 1889 Dec. 16, which is probably correct within one or two days. The light increased from $6^{M}.9$ in the middle of October, which must have been about the minimum, to $5^{M}.6$ for 66 days, and declined for the next 44 days to $6^{M}.3$, when the star disappeared in the sunset horizon. The 110 days of observation, therefore, do not cover a full period.

One of the comparison-stars showed great irregularities, but on the average declined from $6^{M}.6$ to $7^{M}.4$ during the four months of observation, while the DM. gives it as 6.0. Its position is

$$0^{h}\ 9^{m}\ 20^{s}.7, \quad -21^{\circ}\ 0'.6 \quad (1855)$$

The light-curve of the variable was computed twice, viz.: with and without this suspected star, but the time of maximum remained the same for both curves.

4. *U Monocerotis.*

Of this star two maxima and two minima were obtained from 39 observations, between Nov. 15 and Feb. 16 (1889–90).

Min.	1889 Dec.	11.0	Light	0.3
Max.	1890 Jan.	2.5	"	15.2
Min.	" Jan.	21.0	"	7.4
Max.	" Feb.	11.5	"	16.2

The interval between the two minima (the brighter and the fainter) is, therefore, 41.0 days, and that between the two maxima 40.0 days.

There is some evidence of slight change in the comparison-star, DM. $-9^{\circ}.2086$, mag. 7.0.

Most of the time it appeared brighter than

DM. $-9^{\circ}.2069$, mag. 6.8

and only on a few days fainter, viz: on Nov. 15, Jan. 21–22, and Feb. 18.

5. *Algol.*

Two minima were obtained, as follows:

1889 Nov. 15, at $16^{h}\ 10^{m}\pm$, Greenwich M.T.
1890 Feb. 12, at 13 26 " "

The first of these two minima was derived from Professor SCHÖNFELD's mean light-curve (Mannheim 1870). For, although 13 estimates were taken within 3¼ hours, the light-curve had a break of 50 minutes just after minimum. Three results were thus computed, viz: 8^{m}, $5^{m}.5$, 15^{m}, which, combined with proper weights, gave the above result 10^{m}.

The second minimum is well determined from the actual light-curve which was constructed from 20 observations, taken about every 10 minutes, and extending over 3 hours.

6. *R Canis Majoris.*

Of this star three minima were obtained:

(1) 1890 Jan. 16 at $15^{h}\ 0^{m}$, Gr. M.T. mag. 6.3
(2) " Jan. 24 at 12 58 " " 6.4
(3) " Feb. 10 at 12 46 ± " " 6.5

The first minimum	derived	from	15	obs'ns	within	$1^{h}\ 20^{m}$
The second	"	"	13	"	"	1 26
The third	"	"	8	"	"	30

The third minimum is somewhat doubtful, since the observations began only 16 minutes before the minimum, the ephemeris having marked the approximate time as 14 hours.

Georgetown College, Washington, D.C., 1890 *February* 19.

EPHEMERIS OF COMET *d* 1889.

(Continued from page 140.)

BY WILLIAM BELLAMY,

Gr. M.T. 1890	App. α	App. δ	log r	log Δ	Br.
	h m s	° ′			
Mar. 6.5	2 32 16	+18 45.9			
7.5	34 9	18 55.2	0.3689	0.4418	0.22
8.5	36 3	19 4.5			
9.5	37 57	13.7			
10.5	39 51	22.8			
11.5	41 45	31.9	0.3720	0.4504	0.20
12.5	43 39	40.9			
13.5	45 33	49.8			
14.5	47 28	19 58.7			
15.5	49 23	20 7.5	0.3752	0.4588	0.19
16.5	2 51 18	+20 16.2			
Mar. 17.5	2 53 13	+20 24.9			
18.5	55 8	33.4			
19.5	57 4	41.9	0.3783	0.4668	0.18
20.5	2 58 59	50.4			
21.5	3 0 55	20 58.7			
22.5	2 51	21 7.0			
23.5	4 47	15.2	0.3815	0.4746	0.18
24.5	6 43	23.3			
25.5	8 39	31.3			
26.5	10 35	39.3			
27.5	3 12 32	+21 47.2	0.3846	0.4822	0.17

OBSERVATIONS OF COMET *d* 1889,

MADE AT THE HALSTED OBSERVATORY, PRINCETON, WITH THE 23-INCH EQUATORIAL AND SQUARE-BAR MICROMETER.

By D. C. MILLER.

[Communicated by Professor YOUNG.]

Eastern Standard Time = Gr. M.T. —5ʰ	✳	No. Comp.	☄—✳ Δα	☄—✳ Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
1889-90 d h m s			m s	′ ″	h m s	° ′ ″		
Dec. 9 6 2 16	6	6	—0 57.32	+ 4 37.8	0 10 19.50	+ 3 9 18.6	*n*8.998	0.724
9 6 54 2	6	6	—0 54.70	+ 4 57.6	0 10 22.12	+ 3 9 38.4	6.591	0.723
11 7 21 49	7	18	—1 18.88	+ 7 40.4	0 12 16.99	+ 3 30 53.1	8.830	0.720
12 7 1 12	8	11	+3 41.95	+ 2 57.6	0 13 59.50	+ 3 41 19.5	8.566	0.719
13 7 20 49	9	12	+0 54.79	—11 51.7	0 15 11.47	+ 3 52 0.3	8.870	0.717
16 7 18 44	10	10	+2 19.19	—13 1.3	0 19 3.53	+ 4 24 7.6	8.932	0.711
Jan. 12 8 37 55	11	10	+0 29.86	— 5 18.1	0 58 40.56	+ 9 24 58.8	9.519	0.686
13 7 50 22	11	11	+2 3.32	+ 5 13.5	1 0 14.01	+ 9 36 0.2	9.422	0.670
14 7 34 33	12	4	—3 52.05	+ 4 51.1	1 1 49.98	+ 9 47 14.5	9.385	0.665
16 7 17 57	13	6	—2 55.05	— 4 12.0	1 5 4.31	+10 9 31.7	9.348	0.658
17 8 16 59	13	10	—1 12.97	+ 7 32.3	1 6 46.39	+10 21 16.0	9.502	0.674
18 7 45 19	14	10	+2 10.79	— 3 48.1	1 8 23.73	+10 32 15.8	9.438	0.663
22 8 28 17	15	10	—0 20.37	— 3 23.3	1 15 6.50	+11 17 33.9	9.541	0.675
24 7 12 42	16	11	+0 16.42	—10 27.2	1 18 26.16	+11 39 39.0	9.465	0.655

Mean Places for 1889.0 and 1890.0 of Comparison-Stars.

✳	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
6	0 11 14.68	+2.14	+ 3 4 26.3	+11.5	Weisse's Bessel O 153
7	0 11 3.75	+2.12	+ 3 22 58.1	+14.6	" " O 201
8	0 10 15.44	+2.11	+ 3 38 7.4	+14.5	Yarnall 99
9	0 11 17.57	+2.11	+ 4 3 37.5	+14.5	Weisse's Bessel O 207
10	0 16 41.96	+2.08	+ 4 36 54.5	+14.4	Yarnall 163
11	0 58 11.77	—1.07	+ 9 30 52.5	— 5.6	Bar-micr. comp. with Yar. 556 & 620
12	1 5 13.08	—1.05	+ 9 42 26.1	— 5.7	Yarnall 620
13	1 8 0.12	—1.06	+10 13 49.3	— 5.6	" 637
14	1 6 14.04	—1.10	+10 36 9.5	— 5.6	Weisse's Bessel I 50
15	1 15 27.95	—1.08	+11 21 2.7	— 5.5	Yarnall 680
16	1 18 10.83	—1.09	+11 50 11.6	— 5.4	Weisse's Bessel I 257

Jan. 12. Star 11 was observed by mistake for Yarnall 556, and its place afterwards determined by comparisons with Yarnall 556 and 620.

Jan. 13. Windy; telescope vibrating.

Jan. 14. Observations interrupted by clouds.

Jan. 24. Comet barely visible on account of moonlight. During these observations (Jan. 12-18) the comet, though faint, was always easily seen, and the nucleus and a short bushy tail 1½′ long, at a position-angle of about 60°, were still visible.

OBSERVATIONS OF COMETS *f* AND *g* 1889,

MADE AT THE HARVARD COLLEGE OBSERVATORY.

By O. C. WENDELL, ASSISTANT.

[Communicated by Professor EDWARD C. PICKERING, Director.]

1889 Cambridge M.T.	✳	No. Comp.	☄—✳ Δα	☄—✳ Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
			COMET *f* (SWIFT).					
h m s			m s	′ ″	h m s	° ′ ″		
Nov. 18 8 9 21	1	4	+0 50.50	+ 7 35.5	22 44 39.57	+12 8 53.5	9.172	0.673
22 9 38 1	2	6	—0 59.43	— 0 22.6	22 53 40.58	+13 19 40.3	9.188	0.670
22 9 38 1	3	6	—1 8.66	— 1 59.0	22 53 40.52	+13 19 38.8	9.488	0.670
23 9 38 37	3	5	+1 11.48	+12 31.0	22 56 0.67	+13 37 8.8	9.494	0.670
26 10 2 23	4	1	—0 19.25	— 6 15.4	23 3 20.36	+14 30 14.2	9.544	0.674
Dec. 13 8 10 16	5	5	+0 25.50	— 9 5.3	23 51 7.38	+19 26 13.2	9.334	0.564
21 8 34 30	6	4	—0 57.21	— 2 23.4	0 16 59.56	+21 38 36.4	9.132	0.552
23 9 34 12	7	5	—0 52.92	— 0 32.0	0 23 19.26	+22 9 10.5	9.372	0.526

1889 Cambridge M.T.		✱	No. Comp.	☄ — ✱ $\Delta\alpha$	☄ — ✱ $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
				Comet *g* (Borrelly).					
	h m s			m s	′ ″	h m s	° ′ ″		
Dec. 16	8 3 22	1	7	+0 28.54	— 2 32.1	18 11 53.38	+41 34 20.1	9.750	0.784
21	7 57 50	2	6	—1 17.20	— 1 9.5	18 17 11.54	+39 8 2.2	9.706	0.806
23	8 12 20	3	5	+1 21.21	— 2 10.7	18 19 55.14	+36 48 43.2	9.679	0.831

Mean Places for 1889.0 of Comparison-Stars.

✱	α	Red. to app. place	δ	Red. to app. place	Authority
			Comet *f*		
	h m s	s	° ′ ″	″	
1	22 43 47.25	+1.82	+12 0 59.6	+18.4	W_1 22ʰ 890
2	22 54 38.18	+1.83	+13 19 44.3	+18.6	W_1 22ʰ 1106
3	22 54 47.35	+1.83	+13 24 19.2	+18.6	W_1 22ʰ 1111
4	23 4 7.76	+1.85	+14 36 10.8	+18.8	W_1 23ʰ 21
5	23 50 39.90	+1.98	+19 35 28.5	+20.0	W_2 23ʰ 1022
6	0 17 54.71	+2.09	+21 40 39.8	+20.0	Lalande 448
7	0 24 40.06	+2.12	+22 9 52.4	+20.1	W_2 0ʰ 577
			Comet *g*		
	h m s	s	° ′ ″	″	
1	18 11 25.67	—0.83	+41 36 48.5	+3.7	W_2 18ʰ 296
2	18 18 59.24	—0.50	+39 12 8.8	+2.9	W_2 18ʰ 513–14–15 (mean)
3	18 18 34.30	—0.37	+36 50 51.7	+2.2	W_2 18ʰ 499–500 (mean)

COMETS OF THE YEAR 1889.

The dates are in Greenwich Mean Time, and the Elements only approximate.

Designation	Perihelion	☊	π	i	q	φ	Discoverer	Date	Synonym	
		° ′	° ′	° ′		° ′				
I	Jan. 31.209	357 25	340 29	166 22	1.815		Barnard	Sept. 2	*e* 1888	
II	June 10.825	310 42	236 6	163 51	2.256		Barnard	Mar. 31	*b* 1889	
III	June 20.782	270 58	60 8	31 13	1.110		Barnard	June 23	*c* 1889	elliptic?
IV	July 19.270	286 11	345 52	65 57	1.040	84 7	Davidson	July 21	*e* 1889	
V	Sept. 30.012	17 58	343 28	6 4	1.950	28 5	Brooks	July 6	*d* 1889	Lexell's?
VI	Nov. 29.821	330 25	70 1	10 15	1.354	43 3	Swift	Nov. 17	*f* 1889	

The letter *a* is omitted on account of the announcement by Brooks of a comet, January 15.
The Comet *g* 1889, discovered by Borrelly September 12, is probably 1890 I.

TWO HUNDRED EIGHTY-EIGHTH ASTEROID.

A planet of the eleventh magnitude was discovered February 24, by Luther, at Hamburg, in the position

1890 Feb. 24.4650 Gr. M.T. $\alpha = 10^h\ 17^m\ 37^s.6$, $\delta = +14°\ 53'\ 20''$.

Daily motion, -48^s in α, and 6′ northward.

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The Theory of the Reflex Zenith-Tube and Discussion of the Observations of γ Draconis, by Mr. Charles Lane Poor.
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Ephemeris of Comet *d* 1889, by Mr. William Bellamy.
Observations of Comet *d* 1889, by Mr. D. C. Miller.
Observations ot Comets *f* and *g* 1889, by Mr. O. C. Wendell.
Comets of the Year 1889.
Two Hundred Eighty-Eighth Asteroid.

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A DETERMINATION OF THE SOLAR MOTION,

BY LEWIS BOSS.

The determination of the amount and direction of solar motion presented in this communication is based upon the list of stellar proper motions published in No. 200 of the *Astronomical Journal*. There appears to be a number of reasons why it is desirable to undertake this determination. That the motion of the sun through space is an important factor in producing systematic apparent displacements of stars having sensible proper motions may be regarded as a well established fact. But it is also quite possible that important systematic displacements of such stars may also be due to causes which have thus far escaped the search of analysis. The probable existence of such influences is likely to be established through radical variation of the circumstances through which we arrive at successive determinations of the apparent solar motion. New material and variations of arrangement in its use are the means most likely to hasten the discovery of any general facts or laws the operation of which may conspire to produce apparent secular motions of a systematic character among the stars.

In the way of new material, the list of proper motions published in No. 200 of the *Astronomical Journal* offers an advantage. Of the proper motions in question 200 are there pointed out for the first time. Twenty-five others, so far as I know, have never hitherto been employed in a discussion of the solar motion. In fact, out of the 253 stellar motions, selected for the final determination in this paper, only 49 are known to have been previously employed in a similar research.

The stars of the list in question are all contained in the Albany zone, which is 4° 20′ in breadth, and at a mean declination of 3° north of the celestial equator. This arrangement of the material offers at least two distinct advantages.

Assuming a tolerably uniform distribution of the proper motion stars in right-ascension, the determination of solar motion from the stars in this zone is practically independent of the errors introduced by the employment of imperfect precession constants.

Whatever assumption is made regarding the direction of solar motion, the stars in this zone will be very nearly symmetrically arranged with reference to the coordinates of that motion. An incidental practical advantage of no slight value is included under this head, in the greater relative weight of material, and in the facility of solution, as will hereafter appear.

The method employed is substantially that proposed by AIRY (*Mem. R.A.S.*, Vol. XXVIII). For the present purpose the usual system of rectagular equatorial coordinates is adopted.

Then let

μ, μ', μ'' = respectively the proper motion for 100 years of a given star in the right-ascension coordinate, declination coordinate, and in the arc of a great circle. The corresponding means for a large number of stars will be indicated by μ_0, μ_0', μ_0''.

r' = the distance of a given star from the sun, expressed in terms of r, the unit of distance, which for the present purpose will be the mean value of r' for all the stars employed in this discussion.

m = the solar-motion for 100 years, expressed in terms of r as a unit.

$M = \frac{m}{r}$ = the maximum angular value of m as viewed from the unit of distance, r.

A = the right-ascension of the apex of solar motion.

D = the declination of the apex of solar motion.

$x = M \cos D \cos A$

$y = M \cos D \sin A$

$z = M \sin D$

The following expressions are then easily derived:

$$\left.\begin{aligned} \sin\alpha\, x - \cos\alpha\, y &= \mu\cos\delta \\ \sin\delta\cos\alpha\, x + \sin\delta\sin\alpha\, y - \cos\delta\, z &= \mu' \end{aligned}\right\} \quad (1)$$

But since, in the present case, $\sin\delta$ can never much exceed 0.05, it is evident that the sums of the squares and products of the coefficients of x and y in conditional equations of the second form will be practically vanishing quantities in comparison with the sum of the squares of $\cos\delta$, the coefficient of z in the second equation. In the present case, examination will show that the retention of the coefficients of x and y in the second equation would not have affected the determination of z by the five-hundreth part of its computed value — a quantity which is entirely insignificant in relation to the circumstances of solution.

It is furthermore evident that the same reasoning will hold good, though with less force, in reference to the introduction of coefficients to represent the correction required by the adopted constants of precession. The small number of stars employed in this discussion, and the small probability in favor of the supposition that in the mean the values of the *motus peculiaris* approximate sufficiently near to zero, effectually destroy confidence in any corrections to STRUVE's m and n which might have been derived from this discussion. A nominal correction of m might have been derived from the conditional equations in μ, and another for n from the equations in μ'; but in the solution, the value of z would not have been materially influenced under any admissible hypothesis as to the value of Δm. It is also self-evident that the constant error of μ' cannot be determined; and this is perhaps the weak point in the determination of A and D from equatorial stars alone, though an analogous weakness inheres in all determinations of z, with any distribution of stars whatever, since there is no reason to suppose that the constant error of adopted μ_0' would be the same for the different zones into which the celestial sphere might be divided for purposes of solution. On the other hand the constant error of μ can be determined, and the neglect of it might materially affect the concluded values of x and y. We will therefore introduce an unknown, $\Delta\mu$, to represent this effect. The conditional equations will then be of the form:

$$(2)\begin{cases} \Delta\mu + \sin\alpha\, x - \cos\alpha\, y = \mu\cos\delta \\ z = -\mu'\sec\delta \end{cases}$$

In the first solution, 17 stars were excluded. Numbers 204, 5471, 5766, 6073 and 8164, for which μ'' is greater than 100″, were excluded not only on account of their uneven distribution in right-ascension and the controlling influence they would have in certain cases upon individual values of μ_0 and μ_0', but also because it is theoretically probable that the introduction of these stars would seriously impair the correctness of the assumption that r_0' (and consequently M) is nearly the same for the successive groups — a condition which is evidently of great importance, though in the nature of the case it can never be more than approximately satisfied. Of the remaining 12 stars, 504, 2511, 5786 and 6275 were excluded on account of uncertainty in the determination of μ and μ'; numbers 287, 1392, 3651, 4279, 4709, 6898 and 7353, which are probably physically connected with brighter stars (the distance of 6898 from 6893 is however 162″); and number 8009, which was accidentally overlooked.

In order to secure as nearly as practicable the condition of probable approximate equality in the values of M for individual equations, as well as to facilitate the solution, the values of μ and μ' which were to constitute the absolute terms of these equations were brought together in convenient groups, embracing in each not more than one hour of right-ascension. In order to investigate the possible dependence of M upon the magnitude of the stars, the values of μ and μ' were, in the first instance, divided into two series — the first including stars of the magnitude 8.0 or brighter, and the second those of the fainter classes. There were 279 values of proper motion available for use, of which 135 fall in the first series and 144 in the second. The weights are assumed to be identical with the number of stars in each group.

MATERIAL FOR FORMING THE EQUATIONS.

First Series.

Mean Magnitude = $6^M.6$ Mean value of μ'' = 21″.9

α	Wt.	$\mu_0 \cos\delta$	μ_0'	μ_0''
°		″	″	″
13.5	7	+ 8.4	—10.3	30.6
27.4	4	+15.7	+ 2.2	29.4
42.7	4	+ 2.9	— 8.7	20.8
61.9	4	+ 4.5	— 8.3	14.1
78.0	4	+ 8.5	—11.6	20.4
88.5	2	— 9.3	—11.4	15.2
105.7	4	— 9.2	— 1.7	16.8
117.5	6	— 5.4	— 1.8	13.6
130.5	4	+ 8.6	—15.1	20.4
147.4	8	—11.0	— 6.7	20.7
157.2	6	—14.1	—11.4	19.6
169.2	9	—21.3	— 6.0	26.8
180.9	5	+ 5.4	—11.6	30.1
197.8	7	—13.9	— 6.2	22.9
214.1	4	— 9.6	—14.9	26.7
230.2	10	+ 0.1	—13.2	19.7
251.1	7	— 9.6	— 5.2	20.2
267.4	4	— 5.2	—11.4	22.1
275.0	5	+ 3.1	—11.7	18.3
296.2	4	+ 2.0	— 0.9	14.2
316.1	7	—12.6	—14.0	22.3
334.3	20	+ 3.3	— 4.8	21.5
347.9	10	+12.8	— 9.8	25.4

Second Series.

Mean magnitude = $8^M.6$ Mean value of μ'' = 20″.9

α	Wt.	$\mu_0 \cos\delta$	μ_0'	μ_0''
°		″	″	″
9.7	6	+ 0.8	—13.7	27.3
20.2	6	— 5.2	— 5.3	17.2
38.8	7	+15.1	— 8.1	20.4
64.5	5	+ 6.0	— 3.2	21.8
74.2	4	+ 5.0	— 8.8	14.5
90.3	5	— 1.8	— 8.6	15.4
107.5	3	+ 3.0	—10.7	13.7
124.8	5	— 6.2	—10.0	15.9
139.1	7	— 4.4	— 8.7	16.1
148.1	4	—10.9	—10.4	22.1
168.4	4	0.0	— 9.5	14.8
175.1	8	—13.0	—10.9	22.1
188.0	7	— 7.4	—19.1	25.0
200.8	7	—14.2	— 3.2	21.1
216.0	5	—22.7	+ 2.2	23.7
227.7	5	—15.9	— 6.8	23.3

α	Wt.	$\mu_0 \cos\delta$	μ_0'	μ_0''
°		″	″	″
247.4	11	— 6.6	—17.3	22.0
258.8	4	— 8.7	—18.5	21.7
267.7	4	+ 4.7	— 6.0	15.0
282.0	3	+ 1.0	—15.3	15.7
296.1	5	— 1.0	—17.8	19.2
310.2	5	+17.4	— 0.8	34.9
324.7	8	0.0	—13.4	22.4
341.8	7	+ 4.1	—10.8	16.2
352.0	9	+11.2	— 3.9	26.4

Equations after formulas (2) were constructed for each of these groups, and combined in the usual manner into the following normal equations:

From the First Series.

$$\begin{array}{rrrl} +135.00\,\Delta\mu & -\ 6.45\,x & +\ 10.92\,y & = -\ 331''.9 \\ -\ 6.45\,\Delta\mu & +\ 58.22\,x & +\ 5.41\,y & = +\ 58.8 \\ +\ 10.92\,\Delta\mu & +\ 5.41\,x & +\ 76.77\,y & = -\ 695.2 \\ & (\text{From } \mu_0') & +135.00\,z & = +1137.5 \end{array}$$

From the Second Series.

$$\begin{array}{rrrl} +144.00\,\Delta\mu & -\ 11.48\,x & +\ 2.03\,y & = -\ 297''.3 \\ -\ 11.48\,\Delta\mu & +\ 62.91\,x & -\ 0.21\,y & = +\ 187.1 \\ +\ 2.03\,\Delta\mu & -\ 0.24\,x & +\ 81.09\,y & = -\ 760.2 \\ & & +144.00\,z & = +1401.1 \end{array}$$

From the First and Second Series Combined.

$$\begin{array}{rrrl} +279.00\,\Delta\mu & -\ 17.93\,x & +\ 12.94\,y & = -\ 629''.2 \\ -\ 17.93\,\Delta\mu & +121.13\,x & +\ 5.17\,y & = +\ 245.9 \\ +\ 12.94\,\Delta\mu & +\ 5.17\,x & +157.86\,y & = -1455.5 \\ & & +279.00\,z & = +2538.6 \end{array}$$

The solution of these normal equations leads to the following values of the unknown quantities. The probable errors refer to the quantities derived from the solution of both series taken together.

	$\Delta\mu$	x	y	z
	″	″	″	″
First series,	—1.66	+1.64	—8.94	+8.42
Second series,	—1.72	+2.62	—9.32	+9.73
Both series,	—1.69	+2.17	—9.15	+9.10
Probable errors,	±0.69	±1.05	±0.91	±0.48

The value of $\Delta\mu$ might be interpreted as indicating that the adopted value of STRUVE's precession-term, m, requires a correction of —0″.0169 on the basis of this discussion, were it not decidedly at variance with that which may be derived from a discussion on precisely similar principles of more than 4000 faint stars having no appreciable proper motion (and therefore well suited to the determination of m), as already presented in the *Astronomical Journal*, No. 196 (p. 27). The weighted $\Delta\mu$ from that discussion would have been about —0″.45. Moreover, I do not feel especially confident that I have, as yet, sufficiently succeeded in determining the constant errors (from NEWCOMB's system as a basis) in right-ascension to which the zones of BESSEL and LALANDE are liable in the region of the Albany zone*. In fact, this cannot be satisfactorily accomplished at present.

The values of M, A, and D, resulting from the values of the quantities already cited are:

	Mag.	μ_0''	M	A	D
		″	″	°	°
First series,	6.6	21.9	12.39	280.4	42.8
Second series,	8.6	20.9	13.73	285.7	45.1
Both series,	7.6	21.4	13.09	283.3	44.1
Probable errors,			±1.00	±6.9	±3.2

The most striking thing in these results is the near equality of the values of M from the first and second series respectively. If the criterion of distance is considered as dependent upon magnitude in any marked degree, we should have expected that M from the second series would have turned out decidedly smaller than from the first. In fact, considering magnitude alone, the two numbers might have been, 18″.2, for the first, and 8″.0 for the second. The probable errors of the two observed quantities are about ±1″.5. It appears probable, therefore, that for stars having proper motion greater than 10″ per century, the true criterion for estimating their average distances is very nearly independent of the magnitude, and that it is almost wholly some function of the apparent proper motion.

---

* The values of μ originally computed by me, and as they will appear in the forthcoming Catalogue of the Albany Zone, are substantially in agreement with the system of AUWERS's *Fundamental-Catalog*, but not *exactly* so, as will be seen on reference to No. 195 of the *Astronomical Journal*. The correction, adopted in *A J.*, Numbers 196 and 200, to reduce these to the system of NEWCOMB (*American Ephemeris*), is $+0^{s}.0005$. The derivation of this correction, by an inadvertence, is incorrectly explained in *Astr. Jour.* No. 196, p. 25. It was *actually* derived in the following manner:

AUWERS's BRADLEY—BESSEL's BRADLEY, for Southern Stars, (p. 57, of AUWERS's Catalogue)	+0.04
BESSEL's BRADLEY—NEWCOMB (see NEWCOMB's paper) . . .	+0.01
NEWCOMB—AUWERS's *Fundamental-Catalog* (epoch 1880.5) .	+0.01

Sum of these quantities ($+0^{s}.06$) divided by 125, the approximate difference of epochs (Albany Zone—BRADLEY) = $+0^{s}.0005$.

Very likely, AUWERS—BESSEL should have been taken as $+0^{s}.056$ instead of $+0^{s}.01$, and this would have made the correction to my preliminary proper motions in order to reduce them to the adopted (NEWCOMB's) system $+0^{s}.0006$. The difference is not important, in view of other uncertainties.

Mr. FARQUHAR (*Astr. Jour* No. 209) calls attention to a supposed error of mine, and intimates that the correction in question should have been $+0^{s}.0008$. Under a similar, though only momentary misapprehension, I did, at first, compute this correction in precisely the way and with precisely the result that Mr FARQUHAR points out as correct. Mr. FARQUHAR's error seems to spring from the fact that he confuses the proper motions, for which I desired to find a systematic correction, with those of AUWERS's *Fundamental-Catalog*, or of his catalogue of BRADLEY's observations. The systematic correction necessary to reduce the proper motions of AUWERS's BRADLEY to those of NEWCOMB's *Standard and Zodiacal Stars* is probably $+0^{s}.0008$, or $+0^{s}.0009$, for stars between +30° and —20° of declination.

Mr. L. STRUVE finds* for the value of M, 4″.36, which apparently corresponds very nearly to an average secular proper motion of 8″.0 and to an average magnitude 6.0. While it is probable from numerous considerations (adduced by STRUVE himself, *l.c.*) that this value may be somewhat too small — as will also hereafter appear from a special consideration — it is not likely that the true value is much greater than 6″.0 for the case in point, and it cannot be so great as 8″.0. This is less than half the value of M which has just been presented as corresponding to the mean of 279 stars of the average magnitude 7.6, and of apparent proper motion 21″.4, per century. BISCHOF found† for 480 stars of the average magnitude 7.5, which have a mean secular proper motion of 47″.58, the value, $M = 33''.67$. On account of the large proper motions employed in this discussion the relative influence of systematic errors of catalogues, as used, must be very small. Considering these three values of M, in connection with the corresponding values of μ_0'', one is almost irresistibly led to the conclusion, that for large groups of stars, having similar amounts of proper motion in the respective groups, the criterion of distance would be very nearly expressed by the equation:

$$r_0' = \frac{\mu_1''}{\mu_0''}$$

in which μ_1'' is the value of μ'', corresponding to the unit of distance, r. However for reasons which are evident, it is quite certain that r_0', for groups of stars having equal values of μ_0'', would vary quite perceptibly for large differences of magnitude.

It appears, therefore, that there is on the whole greater uniformity in the velocity of motion for individual stars than there is in the amount of light emitted by them. These variations of velocity are undoubtedly very great, and the component of velocity which we ordinarily consider must vary in a still more marked degree. We must, therefore, suppose that both the size and intrinsic brilliancy of the stars, which we see, vary to an enormous extent, and in a degree sufficient to render the criterion of brightness of very little value at all when considered apart from proper motion. The further consideration of this question must, however, be reserved for another opportunity.

Notwithstanding the exclusion of the five stars having proper motion greater than 100″ per century, it appears probable that the determination of solar motion already presented is still injuriously affected by the presence of the larger proper motions. The calculation was, therefore, repeated, excluding all stars for which μ'' amounts to 40″ or more. This removed 13 stars from each of the two series, leaving 253 individual values of μ'' (10″ to 39″) to be considered. These were grouped in order of right-ascension, and in a single series, as follows:

MATERIALS FOR DEFINITIVE EQUATIONS.

No.	Wt.	a	Mag.	$\mu_0 \cos\delta$	μ_0'	μ_0''
		°	M	″	″	″
1	11	12.9	7.7	— 8.0	—10.1	17.3
2	8	24.6	7.8	+ 3.6	— 6.1	17.9
3	9	41.8	7.3	+ 9.1	— 9.9	19.3
4	13	65.8	7.7	+ 4.9	— 6.7	18.5
5	8	82.2	8.0	+ 1.5	— 8.6	15.4
6	5	94.8	7.8	— 2.8	— 6.4	18.6
7	11	113.2	7.2	— 4.1	— 5.1	13.5
8	12	129.6	7.9	— 3.0	—11.5	17.8
9	14	145.8	7.8	— 9.1	— 5.0	16.1
10	10	161.2	7.6	— 9.9	— 9.9	19.4
11	16	174.1	8.0	—10.8	— 8.6	16.5
12	13	190.3	8.1	— 8.2	— 9.1	16.5
13	11	205.5	8.0	—13.8	— 3.2	19.3
14	16	227.7	7.1	— 8.5	— 5.1	15.8
15	17	248.9	7.7	— 7.9	—12.9	19.2
16	12	264.9	7.7	— 3.3	— 8.2	20.0
17	9	284.7	7.4	+ 1.5	—13.0	16.9
18	10	298.6	8.2	+ 2.2	— 5.7	18.8
19	12	317.6	7.9	— 5.6	—14.1	18.9
20	18	334.2	7.5	+ 2.7	— 7.4	21.6
21	18	348.6	7.5	+ 2.2	— 6.9	16.7

The formation and treatment of conditional equations from the foregoing material led to the following normal equations:

$$\begin{array}{rrrrl}
+253.00\,\Delta\mu & -\ 15.06\,x & +\ \ 9.15\,y & = & -\ 907''.8 \\
-\ 15.06\,\Delta\mu & +115.33\,x & +\ \ 7.29\,y & = & +\ 246.3 \\
+\ \ 9.15\,\Delta\mu & +\ \ 7.29\,x & +137.72\,y & = & -\ 874.4 \\
 & (\text{From } \mu_0') & +253.00\,z & = & +2093.9
\end{array}$$

The solution of these equations resulted in the following values of the unknowns, together with those of the quantities depending on them, and with the appended probable errors.

$$\begin{array}{rcrrrcl}
\Delta\mu & = & -\ 3''.24 & \pm 0''.57 & & & \\
x & = & +\ 2.11 & \pm 0.84 & \mu_0'' & = & 17''.80 \\
y & = & -\ 6.25 & \pm 0.77 & \text{Mean Mag.} & = & 7^{\text{M}}.7 \\
z & = & +\ 8.28 & \pm 0.45 & & & \\
M & = & 10.58 & \pm 0.60 & & & \\
A & = & 288^\circ.7 & \pm 7^\circ.2 & & & \\
D & = & +\ 51^\circ.5 & \pm 3^\circ.2 & & &
\end{array}$$

The probable errrors are here markedly smaller than in the first solution, which contains 26 additional motions. Those for x and y and the quantities immediately dependent upon them arise chiefly from the abnormal residuals in the first and twelfth equations for μ_0; and the increased value of D is almost wholly due to these two values of $\mu_0 \cos\delta$. Yet it would not be proper to reject them, nor, in my opinion, to give them lessened weight. The presence of such abnormal values is to be expected from the nature of the case, whenever the means depend upon a comparatively small number of individual values. Furthermore, the individual values of μ are, in general, quite imperfectly determined; since the majority of them virtually depend on the right-ascensions from LALANDE's and BESSEL's zones.

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* *Bestimmung der Constante der Precession*, etc. (*Mem. de l'A. St. P. Tome* XXXV, No. 3) von LUDWIG STRUVE.

† *Untersuchungen über die Eigenbewegung des Sonnensystems*, etc. von JOHANN BISCHOF. Bonn, 1884.

For the sake of comparison the values of the several elements of solar motion as determined by **Struve** and **Bischof** are here quoted in connection with the two sets of values derived in this paper:

	Mean Mag.	μ_0''	M	A	D
		″	″	°	°
Struve	6.0	8.00	4.36	273.3	+27.3
Bischof	[7.5]			285.7	+48.5
		47.58	33.67	290.8	+43.5*
Boss	7.7	17.80	10.58	288.7	+51.5
	7.6	21.4	13.09	283.3	+41.1

The values of A and D obtained by **Bischof** are not more discordant from those obtained by me than is readily explicable from the probable errors. One might assume as the most probable values of A and D for telescopic stars having decided proper-motion:

$$A = 287°; \quad D = +47°$$

But these values are apparently irreconcilable with those obtained by **Struve** and others for the brighter stars. L. **Struve**'s discussion is the most recent and by far the most extensive and elaborate of those which have been undertaken upon the **Bradley** stars. The older determinations of A cluster very persistently about the value 260° and of D, vary from +14° to +40°, with a mean value of about +30°. But one ought not hastily to assume that there is certainly a real difference between the apparent direction of solar motion as it should be determined for the telescopic stars, with comparatively large proper motions, and that which pertains to the brighter stars with comparatively small mean motions.

If we assume, as I have done in the present paper, the present declinations of the *American Ephemeris* as the standard of reference, then the values of μ' (secular) employed by L. **Struve** would require a correction of about $-1''.0$† between the limits of declination from +30° to −20°. The greater number of stars employed by **Struve** fall within these limits, and it is fair to suppose that the values of the constants of solar motion derived from these alone would have been very nearly the same as those which **Struve** has obtained from all the stars used by him. With these premises, it is easy to determine, roughly, what would have been **Struve**'s values of M and D, had he reduced his values of μ' to the system of the *American Ephemeris*. The value of z, as **Struve** determines it, is $+2''.0024$. The new z would be very nearly $+3''.00$. This combined with his adopted values of x and y, $+0''.227$ and $-3''.871$ respectively leads to the following values of the elements of solar motion:

$$M = 4''.9; \quad A = 273°.3 \text{ (as before)}; \quad D = +37°.7$$

Thus about one-half of the discrepancy between the two sets of values for D is, on this hypothesis, accounted for. The remaining differences in the respective values of A and D are probably not much greater than the uncertainties in the data, together with the probable errors of determination, might serve to explain; and we might assume as the most probable coordinates of solar motion:

$$A = 280°; \quad D = +40°.$$

I may be permitted, however, to remark in this connection, that I should not be at all inclined to insist that the μ' (secular) for equatorial stars of the Bradley—Pulkowa system, requires so large a systematic correction as $-1''.0$; nor, in fact to insist upon any special value of systematic correction whatever in the premises. There is no absolute standard of δ and μ', nor of α and μ, which enables us, as yet, to lay any great stress upon the correctness of any particular assumption regarding systematic error: and this, for obvious reasons, is especially the case when we are dealing with supposed systematic error in μ or μ'.

Therefore, I should still be inclined to entertain a suspicion, that the results for the values of A and D, which depend upon telescopic (or other) stars having large proper motions, may possibly indicate a real difference from those derived from stars having, in the mean, small proper motions. This might be supposed to point to the operation of some general law or laws which sensibly affect the apparent motions of the stars, presumably in such a way that the systematic displacements for the stars nearest the sun are greater than for those which are more distant.

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* **Bischof** derives the values of A and D, first quoted, through the employment of **Argelander**'s method, and gives them the preference.

† This is smaller than the correction required by **Auwers**'s *Fundamental-Catalog* between the same limits. (See *Proc. A.A.A.S.*, Saratoga Meeting, 1879.)

OBSERVATIONS OF COMET *d* 1889 (*BROOKS*),

MADE AT THE U.S. NAVAL OBSERVATORY,

BY A. HALL.

[Communicated by the Superintendent.]

1890 Washington M.T.	*	No. Comp.	☄ — * $\Delta\alpha$	☄ — * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
h m s			m s	′ ″	h m s	° ′ ″		
Jan. 9 7 5 23.6	1	20 , 5	−1 8.31	−3 1.1	0 53 18.41	+ 8 50 29.3	9.246	0.649
10 7 22 1.4	2	20 , 5	−0 38.36	+1 11.9	0 55 24.40	+ 9 1 55.9	9.325	0.650
21 6 49 5.9	3	16 , 4	−3 32.46	+0 13.1	1 13 19.24	+11 5 35.5	9.298	0.623
22 6 33 22.4	4	20 , 5	+0 28.10	−4 11.3	1 14 58.93	+11 16 42.8	9.240	0.618
24 6 49 32.2	5	16 , 5	−2 58.25	−1 10.4	1 18 22.47	+11 39 47.1	9.327	0.618
Feb. 10 7 15 27.5	6	16 , 5	+2 36.67	−1 19.7	1 48 6.85	+14 45 24.8	9.507	0.606
14 7 2 5.2	7	16 , 6	+1 32.01	+2 16.2	1 55 19.76	+15 27 37.1	9.499	0.591
15 7 18 33.0	8	20 , 6	+1 32.05	−4 53.6	1 57 9.36	+15 38 11.9	9.536	0.604

Mean Places for 1890.0 of Comparison-Stars.

⁎	α	Red to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	0 54 57.77	—1.02	+ 8 53 38.9	—5.5	$\frac{1}{5}$(3 Struve+2 Schjellerup)
2	0 56 3.80	—1.04	+ 9 0 46.6	—5.6	Weisse's Bessel O, 946
3	1 16 52.75	—1.05	+11 4 57.8	—5.4	" " I, 232
4	1 15 28.10	—1.07	+11 21 2.5	—5.4	$\frac{1}{5}$(4 Frisby–Yarnall+W.B. I, 208)
5	1 21 21.80	—1.08	+11 41 32.9	—5.4	Rümker N.F. 663
6	1 45 31.39	—1.21	+14 46 49.8	—5.3	Bonn Observations
7	1 53 48.96	—1.21	+15 25 26.1	—5.2	Weisse's Bessel I, 918
8	1 55 38.52	—1.21	+15 43 10.6	—5.1	Bonn Observations

NOTES.—Star 1 is a double star, and reductions to principal star of $+0^{s}.05$, and $-0''.5$ have been applied to the meridian observations. The comet was faint in the last three observations.

NOTE ON TRANSIT-OBSERVATIONS OF THE SUN,

BY S. HIRAYAMA.

It may be noticed when observing the sun on a clear day, that the threads of the transit-instrument used in the observation are not distinctly seen, till the sun comes in contact with them. But if the wire is on the image of the sun, it is seen clearly. There is consequently a tendency to get too large a right-ascension of the sun. On a cloudy day, again, the wires of the micrometer can be seen distinctly, even in the case of first contact. This tendency to error in right-ascension observations of the sun on clear days may be avoided by artificial clouds, and for this purpose the use of muslin has been already suggested. But with muslin we get diffraction phenomena which of course have a disturbing effect. Recently I have tried, with good results, the very thin gauzy paper, called *Yoshino-Gami*. Covering the objective of the telescope with this paper has an effect almost identical with the effects of thin clouds. This mode of producing artificial clouds is only useful in the measurement of the solar diameter, for of course the details of the sun's image are quite obliterated.

Observatory, Tokyo, 1890 *Feb.* 1.

ON SOME OBSERVED MINIMA OF *Y CYGNI*,

BY PAUL S. YENDELL.

A watch upon this star, for the purpose of recovering its minimum epoch, was begun 1889 May 31, and continued throughout the summer. It was without success, however, until the evening of September 24, when the star was found below its normal light, and a minimum was observed; the writer being, at the time, unaware of Mr. CHANDLER's previously observed minimum of August 25.

From this date (September 24), every available minimum of the star was observed until December 23; eleven minima being obtained, with several imperfectly observed ones. The observed times are as follows:

Camb. M.T.		w	No. obs.	
	h m			
1889 Sept. 24	10 29.2	2	8	
Oct. 3	10 53.4	5	11	Even'g somewhat cloudy; moonlight.
15	10 43.7	5	20	Moon rose at 9^h 45^m
18	9 52.0	5	19	
24	9 32.0	1	7	Sky streaked with passing clouds.
Nov. 5	8 42.0	5	15	Clear, moon bright.
14	8 56.0	3	14	Some of the observations rather uncertain.
17	8 21.5	4	13	
29	8 0.0	5	16	
Dec. 17	6 50.0	3	10	Hazy sky; some clouds.
23	6 10.0	2	13	

From the use of a mean light-curve, to be referred to below, the following additional minima are inferred:

	h m	
1889 Sept. 27	11 27.1	3 observations
Dec. 2	7 43.8	3 "
11	7 43.5	3 "

Upon comparing the times of observed minima in the first of the above lists with the provisional elements given by Mr. CHANDLER on page 93 of this volume, the period during the time covered by the observations appears to have been, in the mean, about $1^m.5$ shorter than the one there given; and, upon comparing the mean periods indicated by the several intervals between the successive observed minima, a progressive shortening of the period appears to be indicated.

The comparison-stars used are those given by Mr. CHANDLER in Vol. VII, page 47, of this Journal, with the exception of the star designated *b*, which appears to be DM. 34°4193, and was added for the reason, that, to my eye and telescope, the star at its minimum falls well below the comparison-star *p*; the light-scale, formed from all my observations, 167 in number, is as follows.

The magnitudes given are careful estimates from the light-scale, the normal light of *Y* being estimated from a number of observations made for this especial purpose.

	Mag.	L
k	7.0	16.8
l	7.3	13.4
e	7.4	11.8
n	7.8	7.8
p	7.9	6.5
b	8.5	0.0
Y normal	7.35	12.8
" minimum	8.23	2.6

Although the observations were made with the sole view of determining the epoch of the star's minimum phase, and, for that cause, were never carried throughout the entire duration of its light-changes, the variations prove to be of so interesting a character that it is thought that the partial mean light-curve deduced from the observations, 146 in number, from which the eleven minima first above given were obtained, may be of sufficient interest to be here appended: as will be seen, so much of the curve as is here given, closely resembles that of *U Ophiuchi*. The readings are as follows:

Before min. h m	Light	After min. h m	Light
—2 30	9.93	0 0	2.60
20	9.48	+0 5	2.65
10	8.92	10	2.77
2 0	8.36	15	2.90
1 50	7.75	20	3.15
40	7.10	25	3.44
30	6.43	30	3.70
20	5.77	35	4.00
10	5.12	40	4.15
1 0	4.52	45	4.22
0 55	4.27	50	4.27
50	4.03	0 55	4.32
45	3.80	1 0	4.38
40	3.57	10	4.75
35	3.38	20	5.20
30	3.20	30	5.66
25	3.05	40	6.08
20	2.92	1 50	6.40
15	2.80	2 0	6.72
10	2.70	10	7.00
—0 5	2.63	+2 20	7.20
0 0	2.60		

Dorchester, Mass., 1890 *Feb.* 9.

SOME OBSERVATIONS OF VARIABLE STARS IN 1889,

BY EDWIN F. SAWYER.

1. *T Monocerotis.*

This star was observed from 1888 October 9 to 1889 April 28; the observations numbering 49. From these the following epochs of maxima and minima have been deduced, in Cambridge M.T., using the mean light-curve formed from the 1881–83 observations.

Observed Maxima. d h m	Observed Minima. d h m
1889 Jan. 9 23 0	1888 Oct. 9 23 30
Feb. 5 0 34	Nov. 7 22 15
Mar. 3 7 42	Dec. 4 19 25
Apr. 1 4 49	Dec. 29 17 5
Apr. 28 8 15	1889 Jan. 26 20 13
	Feb. 22 17 37
	Mar. 23 11 24
	Apr. 18 13 48

2. *U Monocerotis.*

A very fair series of observations of this star was secured, extending from 1888 December 4 to 1889 April 28, and numbering 41.

The singular behavior of the star as observed by Mr. YENDELL (*A.J.* No. 197, p. 40), is confirmed by my observations; although the times of maxima and minima, as determined from my observations, are not wholly in accord with Mr. YENDELL's deduced results. The odd behavior noted is not confined to this year's observations alone, but has been mentioned in previous years' results, and demonstrated conclusively the erratic nature of the light-changes, and consigns it to the *R Scuti* type, which star in behavior it closely resembles. When first observed on December 4, *U* was very faint, and evidently near minimum. The rise from this date was rapid, and a bright maximum was passed on December 25.5. The star as rapidly declined, and a bright minimum was reached on January 10.5. Another rapid rise, and a second bright maximum was reached on January 23.0, and after an apparent slight fall another maximum was passed on February 4.

Disregarding this deflection, which Mr. YENDELL's observations fail to show, the second maximum was passed January 29.0. From February 4 *U* rapidly declined, and a faint minimum was reached March 4.0. Another rapid rise, and a third bright maximum was passed on March 23.0. A third and bright minimum was passed about April 17, and the star was again near maximum when the observations terminated on April 26.

Maxima	Light	Minima	Light
1888 Dec. 25.5	27.3	1889 Jan. 10.5	19.8
1889 Jan. 29.0	24.8	Mar. 4.0	4.2
Mar. 23.0	26.5	Apr. 17	18.3

The interval between the first and second maxima was 34.5 days, and between the second and third maxima, 53 days. Between the first and second minima the interval is 52.5 days, and between the second and third minima, 44 days.

3. *R Scuti.*

The observations on this star number 15, and extend from June 23 to December 12. *R* was near a faint minimum when first seen on June 23. The increase of light from that time was at first rapid and then very slow, with frequent halts. A maximum was at last reached on August 11, Light = 21.8. It decreased slowly and irregularly, and a bright minimum was passed about September 5. A slow and slight increase occurred and a second and faint maximum was passed about October 7. A second and rather faint minimum was reached November 22. *R* was nearing another maximum when the observations ceased. The interval between the maxima and the minima was the same, or 78 days. Mr. YENDELL's results, recently published, exhibit a singular and unaccountable discordance with the above.

4. *R Coronae Borealis.*

Thirty-seven observations of this star were obtained, extending from January 4 to October 10. When first seen on January 4, *R* was 4 steps > DM. 30°.2682, and 4 steps < DM. 32°.2621, or $6^M.3$. The light remained nearly constant until about June 22, when it suddenly brightened 4 or 5 steps, or $5^M.9$, and after remaining so nearly a month faded to its former brightness and continued nearly constant until the observations ended.

Brighton, Mass., 1890 *March* 12.

5. *S. Coronae Borealis.*

The results given below include the observations of 1888 (unpublished) as well as that of 1889. In 1888 the star was observed from March 6 to July 10, 25 observations. When first seen, on March 6, *S* was 5 steps < DM. 32°.2575, or about $8^M.6$. The increase was regular and very rapid. A maximum was passed on April 16. Maximum brightness 3 steps > DM. 31°.2724, and 3 or 4 steps < DM. 33°.2574, or $7^M.1$. The decrease appeared slow and somewhat irregular. When last seen, on July 10, *S* was = DM. 32°.2577, or $8^M.1$. The observations in 1889 number 10, and extend from March 22 to May 28. *S* was rapidly approaching a maximum when first observed on March 22, being 5+ steps > DM. 32°.2578, and 4 steps < DM. 31°.2719, or $7^M.3$. A maximum was passed on April 9. Maximum brightness 3 steps > DM. 31°.2724, and 4 steps < DM. 33°.2574, or $7^M.1$, the same brightness as last year. Both the increase and decrease were uniform and rapid. Observations were discontinued on May 28, *S* then being = DM. 32°.2578, or $7^M.8$.

NEW ASTRONOMICAL WORKS.

Transactions of the Astronomical Observatory of Yale University. Vol. I. Part II.

The present Part of these Transactions, extending from p. 111 to p. 148, contains a determination by Mr. ASAPH HALL, Jr., of the orbit of *Titan*, the bright satellite of *Saturn*, from observations made with the Yale heliometer in the years 1885–86, and 1886–87. In the first of these oppositions 115 observations were made, and in the second opposition 67 observations. Angles of position and distances were observed by referring the satellite to the ends of the major axis of the apparent ellipse of the ring. The rectangular coordinates of the satellite with respect to the center of the planet were then computed from the observed quantities, these coordinates were compared with those computed from BESSEL's elements, and equations of condition were formed in the usual manner. The final elements, resulting from the solution of the 364 equations of condition, are reduced to the epoch 1886 May 10, Paris M.T.; and compared with the elements of BESSEL and STRUVE. It appears that BESSEL's motion of the perisaturnium, from which he deduced his mass of the ring, needs a position-correction, but in other respects the agreement is very good. The value of the major axis is $176''.570 \pm 0''.0243$, and the reciprocal of the mass of *Saturn* is 3500.5 ± 1.44. This confirms the value found by BESSEL. The probable error of Mr. HALL's result is greater, but he has properly taken in account the errors of the scale divisions used in his observations. This result for the mass of *Saturn* indicates an error of about a second of arc in the mean distance of *Iapetus* found by Professor HALL of Washington.

It is right to mention that this interesting investigation was carried out by means of an appropriation from the Bache Fund of the National Academy of Sciences.

Hülfstafeln zur Berechnung der Parallaxe für Kometen- und Planetenbeobachtungen nach HANSEN, *von Dr. E. von* REBEUR-PASCHWITZ, G. Braun, Karlsruhe.

This quarto pamphlet of 24 pages, reprinted from the third volume of the Grand-ducal Observatory at Karlsruhe, contains, for 169 different observations, the constant factors required in computing the parallax. It gives, for each observatory, a column containing the values of $\pi\rho \cos\varphi' \sin t$ and $-\pi\rho \cos\varphi' \cos t$ in seconds of arc for each tenth minute of hour-angle; also, at the head of the column, the logarithm of $\pi\rho \sin\varphi'$; all being computed with the value $\pi = 8''.848$.

It may be purchased of the publisher for 1.20 marks.

CORRIGENDA.

No. 196, p. 29, col. 1, line 16. For $(a+267^\circ)$, read $(a-267^\circ)$.
No. 200, p. 58, col. 1, line 23. End the sentence at "former" and begin a new one with "Fundamental," with a comma in the place of the first succeeding semicolon.
No. 200, p. 59, star 720; μ', Dist. and Pos. Ang. For $+0''.10$, $0''.23$ and $64^\circ.5$, read $-0''.12$, $0''.24$, and $119^\circ.7$, respectively.
No. 200, p. 60, star 3790; μ', Dist. and Pos. Ang. For $+0''.13$, $0''.14$ and $21^\circ.0$, read $-0''.15$, $0''.16$, and $163^\circ.3$, respectively.
No. 200, p. 62, star 6060; Dist. For $0''.011$, read $0''.11$.
No. 200, p. 62. star 6275; μ', Dist., and Pos. Angle. For $-0''.12$, $0''.15$ and $216^\circ.9$, read $+0''.10$, $0''.13$, and $318^\circ.0$.

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SOME OBSERVATIONS OF VARIABLE STARS IN 1889, BY MR. EDWIN F. SAWYER.
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CORRIGENDA.

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INVESTIGATION OF ERRORS IN LACAILLE'S *COELUM AUSTRALE STELLIFERUM*,

BY B. A. GOULD.

II.

Catalogue-position.			C. A.		Arg. Gen. Catal. for Equinox 1750.0			
No.	R.A.	N.P.D.			No.	Mag	α	δ
	h m s	° ′ ″	page				h m s	° ′ ″
1999	5 39 21.2	134 43 23	77	Assume minute of egress as 43 instead of 42, and decrease both moments by 5s. This makes the observation 5 41 35 and 5 43 4, which gives $5^h\,39^m\,44^s.5$, 44° 53′ 59″	6828	7¾	5 39 14.2	44 54 2
2010	5 40 5.7	146 53 32	52	Reducing for the upper part, we obtain $5^h\,40^m\,7^s.8$, 57° 1′ 59″; and putting ingress 5 41 35 instead of 5 41 40, gives $5^h\,40^m\,5^s.5$, 57° 1′ 17″	6801	7¾	5 40 4.7	57 1 29
2031	5 42 13.6	134 14 15	77	The time of ingress must be decreased by 15s, and that of egress by 5s, making 5 44 15 and 5 44 59, which give $5^h\,42^m\,3^s.3$, 44° 46′ 2″	6877	8	5 42 4.8	44 46 12
2059	5 45 48.7	143 36 55	58	The minute of egress should evidently be 48 instead of 49. If then the ingress be increased, and the egress diminished be 5s, we have $5^h\,45^m\,19^s.4$, 53° 29′ 38″. There is no other star with which this seems capable of identification.	6924	8	5 45 19.7	53 29 22
2055	5 45 27.1	145 8 22	58	There are two stars of 7½M, distant 4s in R.A. and 1′ 43″ in Decl., with the mean of which LACAILLE's position agrees sufficiently.	6920 6922	7½ 7½	5 45 22.7 5 45 26.7	55 9 29 55 7 46
2076	5 47 29.2	126 28 42	100	Both moments were evidently recorded 5m too early.	7161	7¾	5 52 28.2	36 29 17
2077	5 47 40.3	146 34 18	52	Assume ingress at 5 44 51 instead of 5 44 26, which gives $5^h\,47^m\,53^s.0$, 56° 30′ 58″	6973	7¾	5 47 54.0	56 31 23
2078	5 47 45.6	140 34 6	61	This star is evidently G.C. 7009, yet unless the proper motion be improbably large, LACAILLE's observation can only be made accordant by supposing the ingress recorded 45s too early, and the egress 5s too late. Then we should have $5^h\,48^m\,6^s.5$, 50° 26′ 12″	7009	7	5 48 5.1	50 26 8
2081	5 48 27.3	141 12 51	64	Assume ingress at 5 47 18 instead of 5 46 8, which gives $5^h\,49^m\,3^s.6$, 51° 2′ 9″	7029	7½	5 49 1.1	51 2 15
2117	5 53 12.4	133 3 50	84	Assume egress at 5 57 44 instead of 5 58 44, which gives $5^h\,53^m\,13^s.8$, 42° 53′ 6″	7164	7	5 53 13.3	42 53 19
2119	5 54 12.7	133 14 38	85	Assume egress at 5 57 45 instead of 5 58 45, which gives $5^h\,53^m\,41^s.3$, 43° 55′ 40″	7171	7¼	5 53 39.0	43 55 12
2125	5 55 3.1	170 1 39	13	Assume ingress at 5 53 58 instead of 5 54 13, which gives $5^h\,54^m\,56^s.2$, 80° 0′ 17″	6873	8¾	5 54 58.6	80 0 6
2131	5 56 35.8	114 57 27	133	Since the proper motion appears to be insignificant we may assume ingress at 5 54 35 instead of 5 54 40, which gives $5^h\,56^m\,33^s.4$, 24° 56′ 18″. The star is *Oe. Arg.* 4652.	7298	7¼	5 56 31.8	24 55 6
2147	5 58 40.5	154 22 24	37	Assume ingress at 5 56 0 instead of 5 55 30, which gives $5^h\,58^m\,55^s.6$, 61° 19′ 12″	7229	7½	5 58 51.6	61 18 50
2150	5 58 47.3	126 58 10	101	Assume ingress at 6 0 1 instead of 6 0 16, which gives $5^h\,58^m\,39^s.5$, 37° 1′ 9″	7335	8	5 58 41.2	37 1 4

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No.	R.A.	N.P.D.			No.	Mag	α	δ
	h m s	° ′ ″	page				h m s	° ′ ″
2161	5 59 53.7	136 6 23	77	Assume ingress at 5 58 58 instead of 5 58 38, which gives $6^h\ 0^m\ 3^s.1$, 46 9′ 57″	7350	7	6 0 1.3	46 11 1
A 2181	6 2 2.8	118 1 50	127	Using the ingress recorded for no. 2181, we obtain $6^h\ 1^m\ 45^s.7$, 27 54′ 5″	7431	7¾	6 1 45.7	27 53 23
A 2181	6 2 31.7	117 34 1	127	Using the ingress recorded for no. 21 1, we obtain $6^h\ 2^m\ 48^s.8$, 27° 41′ 51″	7465	7	6 2 49.8	27 41 53
2196	6 3 56.3	131 48 38	77	Assume ingress at 6 5 51 instead of 6 6 1, which gives $6^h\ 3^m\ 51^s.1$, 44° 50′ 25″. A change of —5^s in the egress also gives $6^h\ 3^m\ 48^s.2$. 44 49′ 32″, according closely with recent observa ions.	7456	7¾	6 3 48.1	44 49 43
M 2205	6 6 10.0	145 2 18	61	Erroneously reduced in British edition. The observations give $6^h\ 5^m\ 27^s.1$, 54° 54′ 44″. Is identical with no. 2201, δ *Pictoris*, the ingress of which recorded on p. 59 was corrected by 1^m in the British reduction.	7467	5¼	6 5 26.1	54 55 16
A 2208	6 6 57.2	113 58 12	133	Assuming the ingress at 6 4 5 instead of 6 4 13, we obtain $6^h\ 6^m\ 53^s.0$, 24° 0′ 1″, according precisely with the Cordoba position in 1876. The assumption of 6 4 3 however, seems more probable, giving $6^h\ 6^m\ 52^s.0$, 24° 0′ 28″. The absence of large proper motion is indicated by Yarnall 2592.	7584	7	6 6 53.5	24 0 1
A 2216	6 8 23.7	120 57 46	121,3	This star was observed on two nights, 1751 Nov. 28 (p. 121), and 1752 Feb. 23 (p. 123); but the observations neither accord with each other, nor with the Argentine Gen. Catalogue. A small proper motion in Decl. is indicated by the Brisbane Catalogue, and by Taylor, but is quite inadequate to explain the discordance. These can be reconciled by supposing that on p. 121 the egress should be at 6 8 23 instead of 6 8 18, thus giving $6^h\ 8^m\ 25^s.0$, 30° 55′ 46″; and that on p. 123 the moments should be 6 9 27 and 6 10 7 instead of 6 9 32 and 6 9 57 respectively, which assumptions give $6^h\ 8^m\ 23^s.5$, 30° 55′ 26″	7615	7½	6 8 23.7	30 55 45
2235	6 11 45.0	141 24 0	64	Assume ingress at 6 9 10 instead of 6 8 50, which gives $6^h\ 11^m\ 55^s.4$, 51° 20′ 59″	7662	8	6 11 55.7	51 21 4
A 2236	6 11 51.9	119 3 8	121	Assume both moments as 3^s less, giving $6^h\ 11^m\ 48^s.9$, 29° 3′ 9″. Same star as no. 2237.	7705	7½	6 11 48.8	29 3 3
2237	6 11 54.1	119 2 33	123	Assume ingress at 6 11 18 instead of 6 11 33, which gives $6^h\ 11^m\ 46^s.5$, 29° 2′ 32″				
M 2275	6 16 36.3	156 30 57	37	Assume ingress at 6 5 3 instead of 6 15 3, which gives $6^h\ 11^m\ 37^s.6$, 65° 27′ 50″	7579	7½	6 11 35.2	65 27 51
2299	6 19 12.1	142 44 45	65	To reconcile the position with modern observations, the ingress must be made earlier by 10^s, and the egress later by 20^s. Then we have $6^h\ 19^m\ 17^s.7$, 52 40′ 10″. The proper motion is small.	7862	6½	6 19 17.5	52 40 22
A 2306	6 20 35.9	121 2 19	113	Assume egress at 6 20 5 instead of 6 20 10, which gives $6^h\ 20^m\ 33^s.4$, 31° 1′ 16″	7948	7½	6 20 32.9	31 1 17
2315	6 21 40.5	135 35 24	77	Assume ingress of no. 2352 at 6 27 15 to have been interchanged with egress of no. 2315, which gives $6^h\ 21^m\ 45^s.0$, 45° 36′ 54″	7951	7½	6 21 44.7	45 37 29
2352	6 26 8.1	135 9 59	77	Using for ingress the egress of no. 2315, and assuming egress at 6 30 11 instead of 6 30 16, we have $6^h\ 26^m\ 1^s.0$, 45° 10′ 41″	8059	8¼	6 26 0.2	45 11 56
2363	6 27 2.8	167 5 25	17	Assume ingress at 6 24 32 instead of 6 25 52, which gives $6^h\ 26^m\ 26^s.0$, 76° 55′ 54″	Z.C. 966		6 26 25.8	76 55 51
A 2420	6 34 0.3	117 23 11	127	Assume ingress at 6 31 20 instead of 6 31 28, which gives $6^h\ 33^m\ 56^s.4$, 27° 21′ 24″	8329	7¼	6 33 56.7	27 21 24
2441	6 36 28.5	134 50 31	77	Mistake of 5^m in British edition. True position should be $6^h\ 31^m\ 28^s.5$, 44° 50′ 31″	8218	7¾	6 31 25.9	44 51 9
A 2456	6 38 47.3	117 12 36	127	Assume ingress at 6 35 26 instead of 6 35 51, which gives $6^h\ 38^m\ 35^s.2$, 27° 6′ 59″	8468	8	6 38 35.8	27 7 4
A 2461	6 39 15.7	113 51 21	133	Assume egress at 6 41 8 instead of 6 41 3, which gives $6^h\ 39^m\ 18^s.1$, 23° 52′ 28″. Yarnall 2756 indicates no proper motion.	8495	7¾	6 39 16.1	23 52 28
A 2485	6 41 48.4	116 8 31	127	Egress interchanged with that of no. 2503. Using the latter, which is 6 45 8, we have $6^h\ 42^m\ 31^s.3$, 25° 49′ 44″	8586	7¾	6 42 32.4	25 49 45

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No.	R.A.	N.P.D.			No.	Mag	α	δ
	h m s	° ′ ″	page				m s	° ′ ″
A 2496	6 43 2.3	114 10 19	133	**Lacaille**'s observations, which gave the positions of the supposed stars nos. 2538, 2496 and 2497, have been discussed by **Argelander** in *A. N.*, no. 1407, as well as in the B.B. Vol. VII. The stars are very abundant in this region, and numerous errors were made in the haste of recording. Yet no means has been found of explaining either the ingress or the egress noted for no. 2496. I can suggest no better explanation than that the ingress may have been at 6 40 52 instead of 6 39 52, and egress at 6 45 28 instead of 6 45 33. These assumptions give the position $6^h 43^m 30^s.9$, 23° 55′ 38″, which is nearly that of a star in the catalogues of **Piazzi**, **Argelander**, **Yarnall** and Cordoba. The proper motion is insignificant in α, and about 0″.04 northward; and, to represent the place exactly, **Lacaille**'s observations should have been 6 40 48 and 6 45 26.	8619	8	6 43 27.9	23 56 13
A 2497	6 43 5.4	114 1 4	133	Assume egress at 6 46 15 instead of 6 45 15, which gives $6^h 43^m 34^s.5$, 24° 14′ 35″	8621	7	6 43 35.8	24 14 41
A 2503	6 43 40.8	116 21 4	127	Egress interchanged with that of no. 2485. Using the latter, which is 6 42 46, we have $6^h 42^m 57^s.9$, 26° 40′ 2″	8597	7	6 42 57.6	26 39 58
A 2507	6 43 52.3	113 36 35	133	Assume ingress at 6 41 49 instead of 6 41 54, which gives $6^h 43^m 49^s.7$, 23° 37′ 43″	8631	7¼	6 43 49.0	23 37 59
2529	6 46 36.9	123 26 0	113	Assume egress at 6 46 30 instead of 6 46 50, which gives $6^h 46^m 26^s.8$, 33° 30′ 14″	8687	7½	6 46 25.5	33 30 0
2533	6 47 6.1	128 19 11	101	Assume ingress at 6 47 49 instead of 6 47 39, which gives $6^h 47^m 10^s.9$, 38° 21′ 40″	8691	7½	6 47 9.3	38 21 31
A 2538	6 47 28.6	114 40 8	133	Assume, with **Argelander**, ingress at 6 46 45 instead of 6 44 54, which gives $6^h 48^m 22.2$, 25° 5′ 31″	8747	6	6 48 21.3	25 5 32
2542	6 47 57.7	146 23 26	55	If we assume egress at 6 53 5 instead of 6 52 40, we obtain $6^h 48^m 5^s.1$, 56° 25′ 26″ being the place of a 9^M star, but **Lacaille** could hardly have observed it, if so faint as now. The brightest star in the vicinity not observed by him is Gilliss 373 or G.C. 8653, but large changes in both moments would be needful for representing its position.	8662	9	6 48 4.3	56 25 9
A 2545	6 48 13.6	116 59 43	127	Assume egress at 6 49 56 instead of 6 50 56, which gives $6^h 47^m 42^s.8$, 27° 13′ 16″	8732	6½	6 47 43.3	27 13 14
A 2555	6 49 21.7	116 21 51	127	Assume egress at 6 49 50 instead of 6 50 50, which gives $6^h 48^m 52^s.4$, 26° 8′ 30″	8760	7¾	6 48 53.3	26 9 0
A 2558	6 49 36.2	117 36 22	127	Egress interchanged with that of no. 2571. Using the latter, which is 6 51 8, we have $6^h 49^m 41^s.5$, 27° 34′ 22″. But assuming ingress at 6 47 31 instead of 6 47 34, we obtain the position $6^h 49^m 40^s.0$, 27° 33′ 41″	8777	7¾	6 49 38.1	27 33 18
A 2571	6 50 54.5	118 7 55	127	Using egress recorded for no. 2558, which is 6 50 59, we have $6^h 50^m 49^s.9$, 28° 9′ 55″	8808	7¼	6 50 49.5	28 9 9
A 2573	6 51 8.8	115 40 43	127	Assuming egress at 6 50 48 instead of 6 51 3, we have $6^h 51^m 1^s.1$, 25° 37′ 20″, being another observation of Lac. 2572.	8818	7½	6 51 0.6	25 36 15
2591	6 53 9.0	145 37 50	55	Assume ingress at 6 53 35 instead of 6 54 5, which gives $6^h 52^m 38^s.6$, 55° 46′ 15″	8788	8¼	6 52 36.5	55 46 18
2598	6 54 21.7	145 55 17	55	Assume ingress at 6 53 49 instead of 6 54 49, which gives $6^h 53^m 54^s.4$, 56° 3′ 33″	8827	6¾	6 53 53.6	56 3 19
2606	6 56 8.6	146 24 8	55	Assume ingress at 6 53 37 instead of 6 54 47, which gives $6^h 55^m 33^s.2$, 56° 33′ 50″	8876	8	6 55 35.7	56 33 31
A 2623	6 57 23.6	116 3 7	127	Assume ingress at 6 51 53 instead of 6 53 53, which gives $6^h 56^m 53^s.0$, 26° 16′ 30″	8983	7	6 56 52.5	26 17 4
2632	6 58 7.8	147 6 4	55	Assume ingress at 6 54 10 instead of 6 55 15, which gives $6^h 57^m 35^s.6$, 56° 56′ 51″	8927	7½	6 57 34.1	56 57 23
2670	7 3 38.5	127 55 35	101	Reducing for lower part, we obtain $7^h 3^m 36^s.0$, 37° 45′ 10″	9145	8	7 3 36.9	37 46 1
2679	7 4 20.1	128 16 52	101	Assume egress at 7 10 46 instead of 7 9 46, which gives $7^h 4^m 51^s.6$, 38° 4′ 51″	9183	7¼	7 4 53.1	38 4 39
2708	7 7 22.6	131 12 9	95	The only stars below 8^M in this vicinity, excepting Lac 2712, are Gilliss 162 and 163, neither of which can be represented by these observations without changes in both ingress and egress. Yet they have no decided proper motion. The observation must be very erroneous.	9251 9256	7 7½	7 7 21.5 7 7 35.8	41 39 11 41 13 34

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No.	R.A.	N.P.D.			No.	Mag	α	δ
	h m s	° ′ ″	page				h m s	° ′ ″
A 2730	7 8 57.2	116 1 5	127	Assume ingress at 7 6 56 instead of 7 7 31, which gives 7^h 8^m 39^s.4, 26° 8′ 54″	9323	6	7 8 10.5	26 8 45
2759	7 12 7.1	141 23 58	67	Assuming ingress at 7 9 25 instead of 7 9 35, and reducing for the upper part instead of the lower, we obtain 7^h 12^m 4^s.6, 51° 35′ 39″	9354	8¼	7 12 1.6	51 35 4
2807	7 16 38.9	142 6 1	67	Assume egress at 7 21 22 instead of 7 21 2, which gives 7^h 16^m 49^s.2, 52° 2′ 52″	9495	8	7 16 47.4	52 2 37
A 2823	7 19 29.0	120 57 16	121	Observed correctly twice (pages 115 and 123), but on p. 121, the ingress should be 7 19 20 instead of 7 19 25. This gives 7^h 19^m 26^s.6, 30° 56′ 18″, employing Argelander's correction to the reduction-tables; and the mean of the three observations becomes 7^h 19^m 26^s.7, 30° 57′ 26″	9621	6½	7 19 26.0	30 57 22
A 2855	7 24 22.0	117 49 53	127	Assume egress at 7 24 15 instead of 7 25 15, which gives 7^h 23^m 51^s.3, 28° 3′ 11″	9739	7½	7 23 51.2	28 2 30
A 2864	7 25 10.6	115 35 1	127	Assume both ingress and egress one minute earlier than recorded; which gives 7^h 24^m 10^s.6, 25° 35′ 1″, or Lac. 2854.	9752	7	7 24 10.9	25 35 11
2866	7 25 18.9	132 45 35	87	Assume ingress at 7 23 29 instead of 7 22 29, which gives 7^h 25^m 49^s.7, 42° 35′ 5″	9763	7½	7 25 48.8	42 31 55
2871	7 26 32.6	133 55 27	87	Assume egress at 7 29 22 instead of 7 28 22, which gives 7^h 27^m 3^s.4, 43° 44′ 24″	9797	7	7 27 1.2	43 45 29
2879	7 26 48.5	131 40 48	97	Assume egress at 7 27 54 instead of 7 28 54, which gives 7^h 26^m 17^s.3, 41° 52′ 23″	9783	7¾	7 26 18.3	41 51 52
A 2882	7 26 59.8	116 10 25	127	Assume ingress at 7 24 48 instead of 7 25 13 which gives 7^h 26^m 46^s.9, 26° 15′ 59″	9825	7¼	7 26 49.1	26 16 14
2889	7 27 59.4	134 35 34	87	Assume ingress at 7 29 1 instead of 7 28 1, which gives 7^h 28^m 30^s.2, 44° 24′ 50″	9841	7¼	7 28 29.7	44 24 38
2894	7 28 25.3	134 37 0	87	Assume egress at 7 29 23 instead of 7 28 23, which gives 7^h 28^m 56^s.1, 44° 26′ 16″	9851	7½	7 28 54.1	44 26 21
2905	7 29 44.1	139 12 49	73	Assuming ingress at 7 33 17 instead of 7 28 17, we have 7^h 32^m 8^s.8, 50° 2′ 9″, or nearly the position of Gilliss 553. If we also assume the egress to have been at 7 34 26 instead of 7 34 16, we find 7^h 32^m 13^s.9, 50° 0′ 31″	9942	7½	7 32 12.4	50 0 53
2915	7 31 9.2	132 53 28	87	Assume ingress at 7 28 58 instead of 7 27 58, which gives 7^h 31^m 40^s.0, 42° 42′ 39″	9945	7¼	7 31 39.0	42 42 55
2971	7 37 8.4	143 30 10	61	Assume egress at 7 42 11 instead of 7 41 11, which gives 7^h 37^m 38^s.1, 53° 58′ 52″	10105	7¼	7 37 37.3	53 38 59
2989	7 38 28.6	139 44 34	73	Assume ingress at 7 38 21 instead of 7 38 41, which gives 7^h 38^m 19^s.0, 49° 41′ 18″	10144	8¼	7 38 18.7	49 41 25
2995	7 39 3.8	121 3 18	121	Assume ingress at 7 38 26 instead of 7 38 36, which, using Argelander's correction to reduction table, gives 7^h 38^m 54^s.7, 31° 0′ 25″	10217	7½	7 38 56.8	31 0 31
3009	7 40 9.4	156 5 23	37	Ingress exchanged with that of no. 3054. Using the latter value, 7 38 33, we obtain 7^h 41^m 9^s.6, 66° 17′ 55″	10148	7¾	7 41 8.2	66 18 17
3054	7 44 5.9	155 10 57	37	Using the ingress of no. 3009, 7 36 32, we obtain 7^h 43^m 5^s.7, 65° 27′ 46″	10222	6¾	7 43 3.9	65 27 48
3071	7 46 14.4	130 56 25	97	Assume egress at 7 49 48 instead of 7 50 12, which gives 7^h 46^m 1^s.9, 41° 1′ 3″	10413	7½	7 46 0.1	41 0 46
3073	7 46 27.8	119 41 17	121	The catalogue position results from an erroneous repetition in the lower part of the observation of no. 3072, made in the upper part.				
3079	7 47 37.9	141 36 51	67	Assume ingress at 7 47 3 instead of 7 45 3, which gives 7^h 48^m 36^s.0, 51° 57′ 7″	10457	7	7 48 34.2	51 55 51
3094	7 49 32.5	137 13 34	79	Erroneous reduction in British edition. The correct reduction gives 7^h 49^m 53^s.5, 47° 13′ 34″	10510	6¾	7 49 53.8	47 13 42
M 3120	7 52 55.1	138 16 0	73	Assume egress at 7 57 21 instead of 7 57 11, which gives 7^h 52^m 59^s.8, 48° 17′ 38″	10605	6½	7 52 58.9	48 18 17
3126	7 53 58.8	152 19 43	43	Observation must have been made in upper part, as suggested in British edition. The reduction would then give 7^h 53^m 59^s.7, 62° 37′ 27″	10565	6½	7 53 58.2	62 37 27

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No.	R.A.	N.P.D.			No.	Mag.	α	δ
	h m s	° ′ ″	page					
3128	7 54 7.7	130 32 3	97	Reducing for the upper part we have $7^h\,54^m\,10^s.8$, $40°\,37'\,13''$	10668	6¼	7 54 9.3	40 37 20
3129	7 54 14.1	139 49 36	73	I have been unable to reconcile the observations with any star now existing.				
3176	8 0 45.2	138 8 39	73	Assume ingress at 7 59 2 instead of 7 59 52, which gives $8^h\,0^m\,19^s.4$, $48°\,16'\,50''$	10810	7	8 0 19.1	48 17 36
3198	8 3 3.1	141 47 53	67	Assume egress at 8 8 2 instead of 8 8 22, which gives $8^h\,2^m\,53^s.9$, $51°\,51'\,4''$	10881	7½	8 2 50.8	51 50 16
3232	8 6 0.1	135 46 19	79	Assume ingress at 8 3 42 instead of 8 4 2, which gives $8^h\,5^m\,49^s.9$, $45°\,49'\,42''$	10989	7½	8 5 51.9	45 49 53
A 3243	8 7 12.1	118 57 52	123	Egress exchanged with that of no. 3247. Using the latter value, 8 11 25, we have $8^h\,7^m\,48^s.9$, $29°\,14'\,5''$, being position of B. 1962 and that of Lac. 3251 after correction of the ingress on p. 121.	11083	7	8 7 49.0	29 14 27
3245	8 7 18.0	170 29 14	9	Assume ingress at 8 7 30 instead of 8 7 50, which gives $8^h\,7^m\,7^s.6$, $80°\,30'\,52''$	10681	9	8 7 6.0	80 30 56
A 3247	8 7 30.0	119 22 3	123	Using the egress of no. 3243 as 8 10 25 instead of 8 10 10, and assuming ingress at 8 7 17, instead of 8 6 17 we obtain $8^h\,7^m\,31^s.2$, $28°\,56'\,9''$	11076	7¼	8 7 29.5	28 55 55
A 3251	8 8 1.7	119 8 56	121	Assuming ingress at 8 5 3 instead of 8 5 28, we have $8^h\,7^m\,49^s.0$, $29°\,14'\,19''$, being the position of no. 3243 after correction of the egress on p. 123.	11083	7	8 7 49.0	29 14 27
3253	8 8 15.1	146 7 32	55	Assume ingress at 8 8 51 instead of 8 7 56, which gives $8^h\,8^m\,43^s.0$, $55°\,59'\,59''$	11040	8¼	8 8 42.9	55 59 59
3265	8 10 0.5	146 36 31	55	Assume ingress at 8 8 45 instead of 8 7 55, which gives $8^h\,10^m\,25^s.7$, $56°\,29'\,51''$	11093	7¼	8 10 26.1	56 30 16
A 3266	8 10 3.8	118 44 49	123	Assume egress at 8 12 36 instead of 8 12 31, which gives $8^h\,10^m\,6^s.3$, $28°\,45'\,54''$	11152	8	8 10 5.8	28 46 0
A 3267	8 10 4.7	120 21 47	123	Assume ingress at 8 9 40 instead of 8 9 50, which gives $8^h\,9^m\,59^s.8$, $30°\,19'\,36''$	11144	7¼	8 10 2.1	30 19 25
3271	8 10 27.5	142 55 38	61	Assume ingress at 8 11 38 instead of 8 11 43, which gives $8^h\,10^m\,25^s.0$, $52°\,56'\,23''$	11107	8¼	8 10 24.0	52 56 9
3274	8 10 43.6	176 24 9	1	The star is G.C. 9770, but the instrumental errors appear to have made both moments about 6^s late.	C.L. 17	6¾	8 6 14.2	86 29 6
3312	8 15 22.7	121 4 27	115	Egresses interchanged with no. 3316. Using the ingress given for the latter, 8 15 51, we obtain $8^h\,15^m\,11^s.9$, $31°\,8'\,57''$	11291	7	8 15 10.9	31 8 26
3316	8 15 51.9	121 26 23	115	Assume ingress of no. 3312, 8 16 11, which gives $8^h\,16^m\,2^s.7$, $31°\,21'\,55''$	11312	7¼	8 16 2.1	31 22 1
3324	8 17 9.3	128 15 25	103	Assume ingress at 8 13 15 instead of 8 13 20, which gives $8^h\,17^m\,6^s.8$, $38°\,14'\,29''$	11332	7	8 17 7.7	38 15 5
3347	8 19 10.0	144 17 6	61	Assume egress at 8 23 24 instead of 8 24 21, which gives $8^h\,19^m\,9^s.6$, $51°\,55'\,56''$	11349	7½	8 19 7.2	51 56 21
3349	8 19 44.1	141 56 7	67	Assume egress at 8 24 13 instead or 8 24 38, which gives $8^h\,19^m\,31^s.2$, $52°\,0'\,4''$	11371	6¾	8 19 30.0	51 59 38
3351	8 20 9.0	141 51 49	67	Assume egress at 8 25 6 instead of 8 25 16, which gives $8^h\,20^m\,3^s.9$, $51°\,53'\,25''$	11385	7	8 20 1.5	51 53 11
M 3359	8 20 39.4	142 18 15	67	Assume egress at 8 24 35 instead of 8 24 25, which gives $8^h\,20^m\,44^s.6$, $52°\,16'\,21''$	11402	5¾	8 20 44.1	52 16 11
3409	8 25 1.5	135 2 50	79	Assume egress at 8 26 47 instead of 8 27 32 which gives $8^h\,24^m\,12^s.6$, $44°\,51'\,56''$.	11530	7	8 24 13.3	44 51 29
3438	8 28 15.9	137 17 36	79	Assume egress at 8 31 0 instead of 8 30 10, which gives $8^h\,28^m\,11^s.6$, $47°\,9'\,4''$	11633	7¼	8 28 12.5	47 8 16
3445	8 28 31.6	127 4 20	103	Egresses interchanged with no. 3457. Using that given for the latter, 8 29 41, we obtain $8^h\,28^m\,40^s.9$, $37°\,8'\,5''$	11660	7¼	8 28 39.4	37 8 42
3447	8 29 3.0	135 20 56	79	Assume egress at 8 28 22 instead of 8 28 47, which gives $8^h\,29^m\,20^s.2$, $45°\,25'\,14''$	11662	7½	8 29 22.1	45 25 5
3455	8 29 44.6	138 26 38	73	Assume ingress at 8 27 18 instead of 8 27 58, which gives $8^h\,29^m\,23^s.9$, $48°\,33'\,4''$	11656	8½	8 29 23.1	48 33 13
3457	8 29 53.8	126 39 44	103	Egress interchanged with that of no. 3445. Using that given for the latter, 8 28 52, we obtain $8^h\,29^m\,44^s.5$, $36°\,35'\,56''$	11693	7½	8 29 43.5	36 36 7

Catalogue-position.			C. A.		Arg. Gen. Catal. for Equinox 1750.0			
No.	R.A	N.P.D.			No.	Mag	α	δ
	h m s	° ′ ″	page				h m s	° ′ ″
3488	8 33 42.0	128 9 10	103	Assume ingress at 8 30 7 instead of 8 29 37, which gives 8^h 33^m $56^s.6$, 38° 15′ 11″	11809	8¼	8 33 54.4	38 14 47
3489	8 33 42.9	162 20 49	21	Assume egress at 8 36 22 instead of 8 35 22, which gives 8^h 34^m $11^s.3$, 72° 29′ 43″	11663	6½	8 34 8.7	72 29 49
3493	8 34 10.7	128 4 34	103	The stars passing the reticule at this time were numerous and the errors of record exceptionally frequent. The ingress recorded here seems to have been that of G.C. 11832, and the egress that of G.C. 11812; the other moment having been observed for neither.				
3520	8 36 17.4	135 27 27	79	No explanation discovered. To attain accordance with the sky, it would be needful to make the ingress earlier by 15^s, and the egress earlier by 20^s. Then we should have 8^h 36^m $30^s.0$, 45° 26′ 36″	11870	8	8 36 29.0	45 26 41
3523	8 37 0.3	168 10 0	13	Assume ingress at 8 36 29 instead of 8 35 29, which gives 8^h 37^m $32^s.3$, 78° 4′ 6″	11661	8¾	8 37 30.0	78 3 42
M 3528	8 37 41.5	131 41 58	97	Assume ingress at 8 37 58 instead of 8 38 8, which gives 8^h 37^m $36^s.6$, 41° 40′ 6″	11907	7½	8 37 35.1	41 39 42
3530	8 37 44.1	135 5 36	79	Assume ingress at 8 38 11 instead of 8 37 41, which gives 8^h 37^m $59^s.5$, 45° 0′ 21″	11917	6¼	8 38 0.5	45 0 25
3534	8 37 54.2	128 50 11	103	Assume ingress at 8 35 50 instead of 8 35 35, which gives 8^h 38^m $1^s.5$, 38° 53′ 8″	11928	8	8 38 1.9	38 53 33
3538	8 38 13.7	128 4 9	103	Assume ingress interchanged with that of no. 3539. which gives 8^h 38^m $16^s.6$, 38° 5′ 21″	11940	7¼	8 38 14.2	38 4 59
3539	8 38 22.2	128 3 9	103	Assume ingress interchanged with that of no. 3538, which gives 8^h 38^m $19^s.3$, 38° 1′ 57″	11943	7	8 38 17.3	38 1 57
3542	8 38 40.1	135 17 47	79	Assume ingress at 8 38 23 instead of 8 38 3, which gives 8^h 38^m $50^s.4$, 45° 14′ 19″	11945	6½	8 38 50.4	45 14 46
3550	8 39 45.1	163 30 26	21	Assume ingress at 8 36 47 instead of 8 35 47, which gives 8^h 40^m $12^s.9$, 73° 39′ 41″	11829	7	8 40 12.0	73 40 55
3559	8 40 41.0	164 11 27	21	Assume ingress at 8 38 59 instead of 8 39 9, which gives 8^h 40^m 36^s, 74° 10′ 2″	11834	8¼	8 40 36.2	74 10 30
3611	8 47 45.6	166 8 8	17	Assuming both moments 30^s later, we obtain 8^h 48^m $15^s.6$, 76° 8′ 8″; but if we suppose the ingress 35^s later, we shall have 8^h 48^m $18^s.3$, 76° 7′ 36″	12033	7¾	8 48 18.7	76 7 35
3616	8 48 19.1	166 4 58	17	Assume ingress at 8 43 48 instead of 8 44 48, which gives 8^h 47^m $47^s.1$, 76° 11′ 32″	12018	7½	8 47 46.5	76 12 11
3633	8 50 0.5	139 38 52	73	Assume ingress at 8 51 6 instead of 8 49 56, which gives 8^h 50^m $34^s.2$, 49° 50′ 18″	12234	7½	8 50 34.8	49 50 50
3645	8 51 10.3	139 44 55	73	Assume ingress at 8 52 20 instead of 8 51 25, which gives 8^h 51^m $36^s.9$, 49° 53′ 54″	12262	8¼	8 51 37.7	49 53 57
3659	8 52 50.6	148 4 32	55	Both transits must be supposed 30^s later than recorded. Then we have 8^h 53^m $20^s.6$, 58° 4′ 33″, agreeing with a 9^M star.	12292	9	8 53 21.2	58 4 17
3682	8 56 23.1	157 15 55	33	Assume egress at 8 58 22 instead of 8 59 27, which gives 8^h 55^m $51^s.5$, 67° 9′ 50″	12317	7	8 55 49.5	67 9 57
3708	9 0 55.3	151 56 21	43	Assume ingress at 8 57 56 instead of 8 57 6, which gives 9^h 1^m $20^s.6$, 61° 50′ 38″	12452	7	9 1 20.6	61 50 53
3745	9 4 57.3	157 38 59	33	Assume ingress at 8 58 0 instead of 8 59 0, which gives 9^h 4^m $26^s.1$, 67° 44′ 22″	12501	8	9 4 28.3	67 44 40
A 3926	9 25 32.7	120 14 41	123	Interchanging the times of egress, we have 9^h 25^m $17^s.1$, 30 7′ 42″ 9 26 26.9, 29 51 28	13106	7¾	9 25 15.7	30 7 31
A 3936	9 26 11.2	119 44 25			13134	7¼	9 26 27.2	29 51 30
3948	9 27 13.6	127 2 28	103	Assume both moments as 10^m later than recorded, which gives 9^h 37^m $13^s.5$, 37° 2′ 27″	13356	7½	9 37 12.5	37 2 26
3978	9 31 4.6	139 5 14	73	Assume ingress at 9 28 46 instead of 9 29 16, which gives 9^h 30^m $50^s.1$, 49° 0′ 10″	13203	8	9 30 49.8	49 0 51
3982	9 31 55.7	167 21 46	17	Cannot explain this observation satisfactorily. By adding 1^m to the time of ingress, and 20^s to that of egress, we may obtain the approximate place of a small star in the Cape Catalogue.				
4010	9 35 49.4	129 38 30	97	Assume ingress at 9 45 40 instead of 9 35 40, which gives 9^h 45^m $49^s.4$, 39° 38′ 29″. In the British edition 10^m were wrongly subtracted from the egress.	13556	7½	9 45 48.4	39 38 46

Catalogue-position.			C.A.		Arg. Gen. Catal. for Equinox 1750.0			
No.	R.A.	N.P.D.			No.	Mag	α	δ
	h m s	° ′ ″	page				h m s	° ′ ″
A 4026	9 37 30.4	115 16 23	135	Assume ingress at 9 36 52 instead of 9 36 57, which gives $9^h\ 37^m\ 28^s.0$, 25° 15′ 15″	13371	7	9 37 27.2	25 15 50
4078	9 45 44.7	146 30 9	55	Assume ingress at 9 44 14 instead of 9 44 4, which gives $9^h\ 45^m\ 49^s.8$, 56° 28′ 49″	13530 13531	$8\frac{1}{4}$ $8\frac{3}{4}$	9 45 45.4 9 45 49.7	56 26 39 56 28 21
A 4087	9 47 17.0	114 10 39	135	Assume egress at 9 49 28 instead of 9 50 28, which gives $9^h\ 46^m\ 47^s.5$, 23° 57′ 7″	13595	7	9 46 46.7	23 56 56
4108	9 50 48.2	146 53 45	55	Assume egress at 9 58 0 instead of 9 57 10, which gives $9^h\ 50^m\ 58^s.5$, 56° 56′ 22″	13651	$7\frac{3}{4}$	9 50 58.1	56 56 16
A 4124	9 52 42.6	113 53 57	135	Assume ingress at 9 49 27 instead of 9 50 27, which gives $9^h\ 52^m\ 12^s.1$, 24° 7′ 29″	13717	$6\frac{3}{4}$	9 52 12.0	24 7 3
4129	9 53 5.8	144 44 38	61	Assume egress at 9 56 51 instead of 9 57 56, which gives $9^h\ 52^m\ 32^s.7$, 54° 54′ 14″	13695	$6\frac{3}{4}$	9 52 33.3	54 54 1
M 4136	9 53 54.1	136 58 49	79	Interchanging the ingresses of these two stars, we obtain $9^h\ 54^m\ 38^s.7$, 47° 14′ 36″	13750	$7\frac{1}{2}$	9 54 38.6	47 14 33
M 4158	9 57 4.3	136 25 29		9 56 19 .6, 46 9 9	13797	$5\frac{3}{4}$	9 56 19.4	46 9 30
4159	9 57 15.9	137 12 54	79	Assume egress at 10 0 24 instead of 9 59 24, which gives $9^h\ 57^m\ 46^s.7$, 47° 2′ 36″	13817	$6\frac{3}{4}$	9 57 47.6	47 2 18
4164	9 57 39.0	143 11 1	61	Assume egress at 10 1 38 instead of 10 0 38, and ingress at 9 58 0 instead of 9 58 5. These changes give $9^h\ 58^m\ 6^s.0$, 53° 20′ 37″	13815	8	9 58 6.0	53 21 0
4173	9 59 43.1	145 11 36	61	Assume egress at 10 2 53 instead of 10 3 3, which gives $9^h\ 59^m\ 38^s.1$, 55° 13′ 2″	13844	$7\frac{3}{4}$	9 59 37.7	55 13 7
4181	10 0 30.4	134 25 15	87	Assume egress at 10 0 11 instead of 10 1 1, which gives $10^h\ 0^m\ 4^s.8$, 44 34′ 13″	13873	$7\frac{1}{4}$	10 0 3.4	44 34 4
4182	10 0 34.7	134 9 1	87	Assume ingress at 9 58 18 instead of 9 58 38, which gives $10^h\ 0^m\ 25^s.0$, 44° 5′ 23″	13885	8	10 0 22.1	44 5 10
4184	10 0 44.2	154 23 17	39	Assume egress at 10 5 20 instead of 10 3 20, which gives $10^h\ 1^m\ 42^s.2$, 64 35′ 49″	13875	$5\frac{3}{4}$	10 1 43.6	64 35 43
4210	10 4 2.6	127 40 23	103	Assume egress at 10 5 41 instead of 10 6 41, which gives $10^h\ 3^m\ 32^s.0$, 37 52′ 32″	13949	7	10 3 29.3	37 52 15
4211	10 4 14.4	132 40 13	87	Assume ingress at 10 0 40 instead of 10 1 40, which gives $10^h\ 3^m\ 43^s.6$, 42° 51′ 3″	13950	$8\frac{1}{4}$	10 3 42.7	42 51 36
4223	10 5 12.1	133 2 41	87	Assume ingress at 10 0 37 instead of 10 1 37, which gives $10^h\ 4^m\ 41^s.3$, 43 13′ 21″	13977	7	10 4 41.5	43 13 59
4247	10 8 14.1	134 2 49	87	The star seems to be Gilliss 1232, but with an error of 3′. Proper motion does not explain the discordance, and I am unable to reconcile the observations.	14069	$7\frac{1}{2}$	10 8 15.9	43 59 51
4269	10 11 31.0	129 49 53	97	Supposing the ingress at 10 12 53 instead of 10 10 53, and egress at 10 14 24 instead of 10 24 24, we find the position $10^h\ 12^m\ 33^s.3$, 39° 26′ 59″. Diminishing the egress by 5^s, we should have $10^h\ 12^m\ 30^s.8$, 39° 26′ 1″	14185	$7\frac{3}{4}$	10 12 30.3	39 26 18
4288	10 14 27.9	131 50 52	97	Assume egress at 10 18 8 instead of 10 16 8, which gives $10^h\ 15^m\ 29^s.9$, 41 28′ 18″	14250	$6\frac{1}{2}$	10 15 29.7	41 28 21
4302	10 16 33.3	143 47 55	61	Assume egress at 10 21 1 instead of 10 21 41, which gives $10^h\ 16^m\ 13^s.6$, 53° 42′ 10″	14256	$7\frac{1}{2}$	10 16 14.2	53 43 33
4304	10 17 31.1	130 3 41	97	Assume ingress at 10 18 16 instead of 10 16 18, which gives $10^h\ 18^m\ 32^s.1$, 39 41′ 20″	Z.C. 4740	8	10 18 32.6	39 41 21
4311	10 18 32.2	152 10 59	45	Interchanging the egresses of nos. 4311 and 4318, we obtain $10^h\ 17^m\ 53^s.2$, 62 2′ 1″	14280	$7\frac{1}{2}$	10 17 54.1	62 1 52
4318	10 19 11.8	151 44 35		10 19 50 .7, 61 53 45	14324	7	10 19 51.9	61 53 32
4352	10 23 34.0	146 32 16	55	Assume observation to have been in the upper part, which gives $10^h\ 23^m\ 33^s.1$, 57 23′ 7″	14404	7	10 23 28.8	57 23 5
4423	10 31 55.4	169 59 52	13	Assume egress at 10 37 20 instead of 10 36 20, which gives $10^h\ 32^m\ 27^s.6$, 79 51′ 20″	14531	$8\frac{1}{4}$	10 32 28.9	79 52 11
4425	10 32 8.5	148 34 12	51	Assume ingress at 10 29 31 instead of 10 30 19, which gives $10^h\ 31^m\ 15^s.4$, 58 40′ 29″; so that we have a second observation of no. 4420.	14623	$7\frac{3}{4}$	10 31 15.3	58 40 21
4436	10 33 8.7	173 4 20	9	Assume ingress at 10 31 11 instead of 10 34 51, which gives $10^h\ 32^m\ 50^s.1$, 83 1′ 53″	14457	$8\frac{1}{2}$	10 32 49.0	83 3 13
4474	10 37 46.0	161 5 32	27	Assume egress at 10 43 17 instead of 10 43 57, which gives $10^h\ 37^m\ 25^s.4$, 71 9′ 0″	14743	7	10 37 26.6	71 8 5

Catalogue-position. No.	R.A.	N.P.D.	C.A.		Arg. Gen. Catal. for Equinox 1750.0 No.	Mag	α	δ
	h m s	° ′ ″	page				h m s	° ′ ″
4476	10 37 51.0	148 36 50	51	Assume ingress at 10 36 54 instead of 10 36 34, which gives $10^h 38^m 1^s.3$, 58° 34′ 15″; a second observation of no. 4479.	14788	7	10 38 1.9	58 33 38
4482	10 38 18.6	148 34 54	51	Assume egress at 10 39 33 instead of 10 39 23, which gives $10^h 38^m 23^s.6$, 58 36′ 11″; a second observation of no. 4484.	14797	6¾	10 38 22.3	58 36 14
4517	10 43 36.9	127 36 51	103	Assume egress at 10 44 24 instead of 10 45 24, which gives the position $10^h 43^m 7^s.5$, 37 25′ 11″	14925	7	10 43 7.9	37 25 43
4537	10 46 58.5	126 29 15	103	The minute of both ingress and egress, like that of the egress of the preceding star in the same zone, should be 44 not 45. This gives the position $10^h 45^m 58^s.5$, 36° 29′ 45″	14983	7½	10 45 56.3	36 30 41
4546	10 48 28.0	132 12 23	91	Interchanging egresses of nos. 4546 and 4551, and assuming ingress of former at 10 48 26 instead of 10 48 36, we find the positions $10^h 48^m 14^s.7$, 42° 11′ 5″ 10 48 53.8, 42 3 9	15032	7¾	10 48 14.1	12 10 1
4551	10 48 45.5	132 0 0			15049	8	10 48 51.0	42 3 12
4547	10 48 31.0	142 10 57	67	Assume egress at 10 52 31 instead of 10 52 41, which gives the position $10^h 48^m 25^s.8$, 52 12′ 31″	15029	7¾	10 48 23.7	52 12 19
4578	10 52 54.1	175 37 59	5	Assume ingress at 10 52 24 instead of 10 53 24, which gives the position $10^h 52^m 27^s.5$, 85° 36′ 43″	14883	8½	10 52 25	85 34 33
A 4582	10 53 19.1	119 4 11	123	Supposing ingress at 10 52 40 instead of 10 52 47, we have the position $10^h 53^m 15^s.6$, 29° 5′ 42″	15162	7¼	10 53 14.7	29 5 31
4590	10 54 27.3	135 58 12	79	Reducing observation for the upper part, we have the position $10^h 54^m 29^s.3$, 46° 6′ 38″, and the same star as no. 4591	15188	6¾	10 54 29.9	46 5 49
4591	10 54 35.3	136 5 58	83	Assuming the two recorded moments to be 5^s late, as shown by no. 4590, as well as recent observations, we have the position $10^h 54^m 30^s.3$, 46° 5′ 58″				
A 4617	10 57 5.1	118 23 11	123	Assume ingress at 10 58 50 instead of 10 58 5, and egress at 10 59 43 instead of 10 58 43. These changes give the position $10^h 57^m 57^s.5$, 28 26′ 29″	15283	7	10 57 56.2	28 26 33
A 4655	11 2 28.3	114 45 33	135	Assume ingress at 11 0 37 instead of 11 0 47, which gives the position $11^h 2^m 23^s.4$, 21 43′ 15″	15388	8	11 2 24.6	24 43 2
4724	11 10 46.2	163 45 42	21	Assume egress at 11 16 23 instead of 11 16 28, which gives the position $11^h 10^m 43^s.6$, 73° 46′ 28″. There is little, if any, proper motion.	15532	6½	11 10 43.2	73 46 35
M 4774	11 20 13.7	148 5 42	55	Interchanging the egresses of nos. 4774 and 4775, we obtain the positions of o_1 and o_2 *Centauri.* $11^h 20^m 20^s.3$, 58 3′ 57″ 11 20 22.1, 58 7 58	15755	5¼	11 20 19.6	58 3 53
M 4775	11 20 28.7	148 6 14			15756	5½	11 20 22.6	58 8 18
4787	11 21 51.5	136 57 27	79	Assume egress at 11 28 44 instead of 11 24 44, which gives the position $11^h 23^m 54^s.8$, 46° 15′ 24″—C_2 *Centauri.*	15841	5½	11 23 54.3	46 15 33
4807	11 24 37.5	127 36 52	103	Assume ingress at 11 20 27 instead of 11 20 17, which gives the position $11^h 24^m 42^s.5$, 37° 34′ 46″	15870	7¼	11 24 44.0	37 34 41
4811	11 25 5.3	172 47 22	9	Assume ingress at 11 23 29 instead of 11 24 29, which gives the position $11^h 24^m 37^s$, 82° 43′ 20″	15792	8	11 24 17	82 43 2
4820	11 26 11.2	149 28 6	51	Assuming ingress at 11 21 11 instead of 11 21 36, we obtain the position $11^h 25^m 58^s.3$, 59° 31′ 8″	15890	7¼	11 25 59.2	59 31 16
4834	11 27 26.1	150 14 7	51	Assume ingress at 11 22 16 instead of 11 23 16, which gives the position $11^h 25^m 57^s.0$, 60° 6′ 21″	15889	7¾	11 25 58.1	60 6 10
A 4845	11 28 41.5	117 47 31	129	Assume ingress at 11 27 39 instead of 11 27 34, which gives the position $11^h 28^m 44^s.0$, 27° 48′ 38″	15972	6½	11 28 43.3	27 49 9
A 4867	11 31 32.6	118 22 6	123	Assume egress at 11 33 3 instead of 11 33 8, which gives the position $11^h 31^m 30^s.1$, 28° 21′ 0″	16043	7	11 31 29.3	28 21 46
A 4894	11 35 26.5	119 37 59	123	Assume egress at 11 39 4 instead of 11 40 4, which gives the position $11^h 34^m 55^s.9$, 29° 51′ 12″	16117	7¾	11 34 54.5	29 51 59

CONTENTS.

INVESTIGATION OF ERRORS IN LACAILLE'S COELUM AUSTRALE STELLIFERUM, II, BY DR. B. A. GOULD.

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No. 215.

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NEW DOUBLE STARS,

DISCOVERED WITH THE 18½-INCH REFRACTOR OF THE DEARBORN OBSERVATORY, EVANSTON, ILL

BY PROF. G. W. HOUGH, DIRECTOR.

The following list of Double Stars includes only the closer pairs discovered since the 18½-inch refractor was remounted on the new sight at Northwestern University, Evanston, Illinois.

In the month of November, 1887, the instruments in Chicago were dismounted, and the old site abandoned. The 18½-inch refractor was again remounted in the month of August, 1889.

The new observatory building is the gift of JAMES B. HOBBS, Esq., and was erected at a cost of twenty-five thousand dollars; it is a first-class structure in every respect. The equatorial room is thirty-four feet in diameter in the clear, on the inside. The dome is of iron, with a continuous opening four feet in width, extending from the horizon to two feet beyond the zenith. The shutter, for covering the opening, extends over the whole hemisphere, somewhat similar to that of the Greenwich dome; being pivoted on one side, and resting on a track on the opposite side. The shutter may be opened or closed in less than ten seconds, requiring for this purpose a force of ten pounds applied to an endless rope.

The moving parts of the dome weigh ten tons; it may be turned, by one person, through a complete revolution in one minute. The direct force, applied at the circumference of the dome, necessary to revolve it, varies between fifteen and thirty pounds, depending on the temperature. In very cold weather the friction is greater than in warm weather.

In the new observatory, the ease with which the shutter and dome may be manipulated, greatly increases the possibilities for observation.

The few months that I have used the telescope here, have led me to believe that the atmospheric conditions will be much better here than in Chicago, especially in the clearness of the air. During the last two or three years in Chicago, everything had a yellowish appearance, undoubtedly due to the smoke of the city. In the present location it is not probable that there will ever be any trouble of that kind.

The majority of the double stars in the following list are difficult objects; being either excessively close, or else very unequal in magnitude.

The list contains twenty-seven pairs, which may be classified as follows: Nine pairs have a distance of less than 0″.5, five pairs are between 0″.5 and 1″, and thirteen pairs are between 1″ and 3″. The pairs having a greater distance than 1″ are generally very unequal in magnitude.

In the table of observations the sign ± indicates an estimation.

The powers of the eye-pieces used are as follows: III, 390, V, 925.

For the easy identification of a close or otherwise difficult pair, I have indicated its position with reference to a neighboring star.

ABBREVIATIONS USED.

Brux. denotes *Annales de l'Observatoire Royal de Bruxelles*, tome VI. *Catalogue de* 10792 *Étoiles*.
W. denotes Weisse's Bessel.
DM. denotes Bonn *Durchmusterung*.
Schj. denotes Schjellerup.
Port. denotes Cincinnati Observatory. J. G. Porter. Catalogue of 4050 Stars.
Tacc. denotes Tacchini. Catalogue of 1001 Southern Stars, Washburn Observatory, Vol. III.
β denotes S. W. Burnham.
Ho. denotes G. W. Hough.

RIGHT-ASCENSION AND DECLINATION FOR 1880.0.

Brux. 294.

R.A. $0^h\ 39^m\ 42^s$. Decl. $-17°\ 5'$.

1889.994	190 ±	1.8 ±	6 – 9	III
90.006	191.0	2.00	6 – 9	III

This is a fine, easy pair. I do not find it, however, in any catalogue I have.

W_2 I, 1000.

R.A. $1^h\ 41^m\ 32^s$. Decl. +24° 4′.

1889.851	N	0.5 ±	7 – 7	III
90.046	180.8	0.36	7 – 7.5	V

A close pair. 7-mag. star, S. 30′ and following 55^s.

11 *Arietis.*

R.A. $2^h\ 0^m\ 1^s$. Decl. +25° 8′.

1889.854	340 ±	1.5 ±	6.5 – 12	III
90.071	328.8	1.03	6.5 – 12	V
.077	331.5	1.15	6.5 – 12	V
1890.07	330.1	1.09	6.5 – 12	

A difficult pair, owing to the closeness and inequality of the components.

W_1 II, 537.

R.A. $2^h\ 32^m\ 51^s$. Decl. —2° 6′.

1889.950	N	1″ ±	8 – 8.2	III
90.046	0.7	0.91	8 – 8.2	III

A fine, easy pair. 7-mag. star, N. 7′ and preceding 31^s.

W_2 II, 1177.

R.A. $2^h\ 50^m\ 19^s$. Decl. +16° 45′.

1889.911	n.p.	2.5 ±	8 – 11	III
.942	308.6	2.93	8.2 – 11	III
90.052	307.2	2.74	8 – 11	III
1889.99	307.9	2.83	8.1 – 11	

An easy pair.

DM. 16°376.

R.A. $2^h\ 52^m\ 41^s$. Decl. +16° 34′.

1890.052	24.5	2.12	9 – 9	III
.077	22.3	1.93	9.3 – 9.3	III
1890.06	23.4	2.02	9.2 – 9.2	

8-mag., double, precedes $2^m\ 24^s$, and 10′ N.

W_1 III, 235.

R.A. $3^h\ 14^m\ 41^s$. Decl. +0° 44′.

1890.120	168.9	1.22	8 – 10.5	V
.148	166.2	1.13	8 – 10.5	III
1890.13	167.5	1.17	8 – 10.5	

7-mag. star, precedes $1^m\ 10^s$ and same decl.

W_1 III, 777.

R.A. $3^h\ 42^m\ 14^s$. Decl. +14° 36′.

1890.017	330.1	0.49	8.2 – 8.5	V
.077	342.5	0.49	8.2 – 8.5	V
.123	340.9	0.45	8 – 8	V
1890.07	337.8	0.48	8.1 – 8.3	

A close pair; possibly an error of 10° reading at first observation. 8.5-mag. star, N. 5′ and following 26^s.

DM. 28°627

R.A. $4^h\ 1^m\ 44^s$. Decl. +28° 20′.

1890.006	N	0.4 ±	8 – 8	III
.115	348 ±		8 – 8	V
.120	345.7		8 – 8	V
.123	345.1	0.30	8 – 8	V
.148	348.8	0.29	8 – 8	V
1890.13	346.5	0.29	8 – 8	

A very close pair, and difficult. 42 *Tauri*, N. 20′ and preceding $2^m\ 9^s$.

DM. 19°689.

R.A. $4^h\ 10^m\ 2^s$. Decl. +19° 22′.

1889.994	S	0.4 ±	7 – 7	III
90.115	172.5	0.37	7 – 7	V
.120	180.4	0.36	7 – 7	V
1890.12	176.4	0.36	7 – 7	

A close pair. 8-mag. star, S. 6′ and following 40^s.

SDM. —18°.1374.

R.A. $6^h\ 13^m\ 3^s$. Decl. —18° 22′.

1890.123	prec.	1.5 ±	8.2 – 10	III

7-mag. star, S. 4′ and preceding 40′ (arc).

DM. 13°1329.

R.A. $6^h\ 29^m\ 17^s$. Decl. +13° 48′.

1890.109	133.0	1.37	7.5 – 12	III

9-mag. star in field, $p = 155°\pm$, $s = 60''\pm$. A rather difficult pair, owing to the closeness and inequality of the components.

Schj. 2484.

R.A. $6^h\ 56^m\ 6^s$. Decl. +13° 16′.

1890.123	foll.	1″ ±	8 – 9	III

A fine, easy pair. 7-mag. star, S. 25′ and following $1^m\ 2^s$.

45 *Geminorum.*

R.A. $7^h\ 1^m\ 29^s$. Decl. +16° 7′.

1890.123	foll.	3″ ±	6 – 13	III

Rather difficult, owing to the inequality of the components.

Port. 1221.

R.A. $7^h\ 9^m\ 38^s$. Decl. —20° 49′.

1890.071	N.	1″ ±	9 – 9.2	III

South star of a small triangle.

Brux. 3080.

R.A. $7^h\ 17^m\ 27^s$. Decl. —20° 58′.

1890.071	foll.	0.6 ±	8.5 – 10	III

β 199. N. 1′ and following $2^m\ 30^s$.

SDM. —20°1893.

R.A. $7^h\ 17^m\ 30^s$. Decl. —20° 56′.

1890.071	40 ±	1.5 ±	9.5 – 9.5	III

In the field with preceding pair.

Tacc. 834.

R.A. $18^h\ 16^m\ 6^s$. Decl. —26° 14′.

1889.711	140 ±	0.5 ±	8 – 8	III

A close pair. 6.5-mag. star, N. 5′ preceding $2^m.5$.

Tacc. 845.

R.A. $18^h\ 21^m\ 33^s$. Decl. —25° 7′.

1889.720	foll.	2″ ±	7 – 7	III
.772	99.0	1.62	8 – 8	III

7-mag. star, S. 12′ and following 24^s.

Port. 3050.

R.A. $18^h\ 29^m\ 32^s$. Decl. —20° 25′.

1889.753	s.f.	1″ ±	7 – 10	III

8-mag. star, N. 8′ and following 8^s.

W_2 XIX, 41.

R.A. $19^h\ 3^m\ 39^s$. Decl. +19° 2′.

1889.736	foll.	0.4 ±	8 – 8	III

The following star of a group of three.

W_2 XX, 662.

R.A. $20^h\ 19^m\ 25^s$. Decl. +29° 0′.

1889.772	80 ±	1.5 ±	8.2 – 8.2	III
.782	63.4	1.62	8.2 – 8.2	III

Anon.

R.A. $20^h\ 19^m\ 15^s$. Decl. −27° 1′.

1889.720	52.5	2.92	8 – 8.2	III
.791	56.6	2.26	8.2 – 8.4	III
1889.75	54.5	2.59	8.1 – 8.3	

8-mag. star, N. 3′ and preceding 41^s.

W_2 XXII, 694.

R.A. $22^h\ 31^m\ 56^s$. +26° 49′.

1889.821	56 ±	2″ ±	8 – 10	III
.840	53.5	1.81	8 – 10	III
.843	55.5	1.83	8 – 10	III
1889.84	54.5	1.82	8 – 10	

Ho. 186 is N. 15′ and precedes 55^s.

DM. 28°4116.

R.A. $22^h\ 40^m\ 3^s$. Decl. +28° 45′.

1889.791	120 ±	0.4 ±	8 – 8	III
.793	112.9	0.3 ±	8 – 8	V

A very close pair, too difficult for distance. 7-mag. star, S. 5′ and preceding $1^m\ 49^s$.

W_2 XXII, 1010.

R.A. $22^h\ 45^m\ 42^s$. Decl. +25° 45′.

1889.807	160 ±	0.3 ±	6.5 – 6.5	V

A very close pair. 9-mag. star, S. 60″ ±.

W_2 XXIII, 381.

R.A. $23^h\ 20^m\ 4^s$. Decl. +27° 3′.

1889.793	62.7	0.42	8 – 8	V
.909	59.7	0.46	8 – 8	V
1889.85	61.2	0.44	8 – 8	

A close pair. In DM. $7^M.6$. 8-mag. star, S. 60″ ±.

DIFFERENCE OF DECLINATION OF 43 *H. CEPHEI* AND *BRADLEY* 95,

By GEORGE C. COMSTOCK.

In the *Sidereal Messenger* for September, 1888, I have called attention to the advantages for the determination of the value of a revolution of a micrometer-screw which are presented by a properly selected pair of polar stars, and have suggested the use of 43 *H Cephei* and *Br.* 95 for this purpose. Observations of these stars, made since the date of that article, have served to confirm the opinion then expressed, and I take this opportunity of publishing the results of a discussion of the $\Delta\delta$ of these stars for the use of others who may wish to employ them for a similar purpose.

The approximate coordinates of the stars for the epoch 1865.0, derived from the Pulkowa catalogue of 3542 stars, are:

43 *H. Cephei*,	R.A. = $0^h\ 50^m\ 52^s.1$,	Decl. = 85° 31′ 52″,	$\mu = +0^s.0690$,	$\mu' = -0''.005$
Bradley 95,	$0\ 54\ 8.9$	86 25 28,	+0.0592,	−0.016

These coordinates have furnished the basis for the discussion of the difference of declination of the stars. The authorities available for this discussion, making use of those only which contain places of both stars, in order to avoid as far as possible the effect of systematic errors in the catalogues, are given in the table below. For the data from the catalogues of Piazzi and Henderson, I am indebted to Professor A. Hall; these catalogues not being accessible to me.

By means of Oppolzer's precessions and the data of the Pulkowa catalogue, the proper motions being transformed to correspond to Oppolzer's precession-constants, I derive the following expression for the difference of declination of the stars, at any epoch, T.

$$\Delta\delta_T = \Delta\delta_{1865} - 0''.076\,(T-1865) - 0''.00028\,(T-1865)^2 - 0''.00000075\,(T-1865)^3$$

with which the data furnished by the several authorities were reduced to the epoch 1865.0. Each value of $\Delta\delta$ thus reduced furnishes an equation of the form

$$X + (T-1865)\,y = n,$$

and the solution of these equations furnishes a correction to the assumed difference of declination of the stars, and to the assumed coefficient of the first power of the time.

The designations of the several authorities employed seem to require no further explanation than the statement that Greenwich 1881–86 refers to the annual volumes for these and intermediate years, and that *Madison* denotes a series of observations of the stars made, at my request, by Professor Brown and Mr. Egbert with the meridian-circle of the Washburn Observatory. In this series of observations each star was observed on each night, and the results therefore possess the advantages of differential observations, and have received large weight in the discussion. The weights assigned to the several authorities are based upon the number of observations, the probable (accidental) error of a single observation, and an estimate of the probable amount of outstanding error of graduation of the circle employed. This last element has very much reduced the weight of results obtained with circles whose division-errors have not been investigated.

Authority	Date of Observ'n	No. of Obs.	Obs'd $\Delta\delta$	w	v
			′ ″		″
Auwers's Bradley	1752.0	59–29	53 41.7	2.0	+0.71
Fedorenko	1790.0	2– 2	40.6	0.0	+0.18
Piazzi	1800.?	5– 6	42.0	0.5	—1.78
Groombridge	1807.5	7– 6	40.2	0.5	—0.46
Schwerd	1827.7	2– 2	37.6	0.5	+1.05
Henderson	1838.0	10–10	38.4	2.5	—0.38
Radcliffe I	1848.4	12– 7	38.5	2.0	—1.01
Paris	1849.4	6– 1	35.8	0.5	+1.68
Carrington	1855.0	3– 4	37.1	1.0	—0.27
Radcliffe II	1857.4	4– 5	37.4	2.0	—0.91
Brussels	1864.1	3– 4	36.2	2.0	—0.12
Pulkowa	1865.6	4– 4	36.5	7.0	+0.18
Greenwich 1864	1866.2	9– 3	36.3	3.5	—0.17
" 1872	1874.2	3– 4	34.6	3.0	+0.96
" '81–'86	1884.7	26–16	34.8	6.0	—0.35
Madison	1888.7	8– 8	53 33.8	8.0	+0.29

The residuals v, given above, correspond to the following least-square solution of the data, in which

$$t = \frac{T - 1865}{100}$$

$$\begin{array}{lllll} \Delta\delta = & 3216''.07 & -7''.91\,t & -2''.81\,t^2 & -0''.75\,t^3 \\ & \pm 0''.11 & \pm 0''.34 & & \end{array}$$

Washburn Observatory, 1890 *March* 11.

This solution, which I adopt as the definitive value of $\Delta\delta$, represents the difference of the mean declinations of the stars, and requires the following correction to reduce it to the difference of the apparent declinations:

$$Corr. = -0''.011\,\tau + [8.906]\,A + [8.210]\,B + [8.365]\,C + [7.475]\,D$$

in which A, B, C, D are the Besselian star-numbers.

In the formula for the difference of the mean declinations, the variations of the proper motions are included in the terms containing the higher powers of the time.

A detailed statement of the methods of observation and reduction which I have found most advantageous in the use of these stars for the determination of the value of a revolution of a micrometer-screw, may be found in the forthcoming Vol. VI of *Publications of the Washburn Observatory.*

It is hardly necessary to remark that 43 *H. Cephei* is an almanac star, and that its coordinates and those of *Br.* 95 for any date are therefore very easily obtained.

A NEW VARIABLE OF SHORT PERIOD IN *ANTLIA*.

By H. M. PAUL.

[Communicated by the Superintendent of the U.S. Naval Observatory.]

I wish to announce the discovery of a new variable star in the constellation *Antlia*, whose period is the shortest yet known. It is certainly as short as $0^d.480 = 11^h\,31^m$, with a slight possibility that it may be as short as $0^d.324 = 7^h\,46^m$.

The star is 12 *U.A. Antliae* = Lacaille 3892, and its position for 1875.0 is

$$\alpha = 9^h\,26^m\,50^s.1 \qquad \delta = -28^\circ\,4'\,40''$$

During the first three months of the year 1888 I had occasionally compared this star with some of its neighbors, especially with its nearest one, 7 *U.A. Antliae*, which is of a reddish color, but had attributed the evident discrepancies to probable variation in the latter, and to the varying effects of haziness and great zenith-distance. A more careful examination of the results, however, in the first part of April, seemed to indicate that 12 *U.A.* was the variable, and that its changes of brightness were frequent, and after the evening of 1888 April 13, when it appeared unquestionably to brighten up two or three-tenths of a magnitude in thirty or forty minutes, it was followed on every possible occasion till about the first of June. But, as the star was already well over towards the SW. horizon before twilight ended, even in April, most of these observations were of a very heterogeneous character, made under all possible conditions as to moonlight, twilight, haze and fog, many of them close to the horizon, and with field-glasses, comet-seeker, and 9-inch equatorial, with the added difficulty that the reddish neighbor was the only convenient comparison-star with the latter instrument.

Nevertheless, with the help of the scattered single comparisons of the three months preceding, I was able, from the whole, to show that the period must be at least as short as $0^d.48$, and to indicate the approximate form of the light-curve. The principal point of uncertainty was as to the possibility of the period being as short as about $0^d.324$. These results I announced at the Cleveland meeting of the A.A.A.S. in the summer of 1888, but refrained from publishing them at the time; fully expecting to clear up all uncertainty about the period, and publish a much more complete investigation from the observations of the succeeding winter.

Since that time I have observed the star regularly through the opposition of 1888–9, and through the present winter to date, but, on account of pressure of other duties in the day-time, I have not as yet had time to reduce either of these season's observations completely, and the data given below depend mostly upon the first season's observations. As many of these were of such a doubtful character, I should hardly venture to offer them now as at all definitive, had they not been substantially confirmed by a rough examination of the results of the two succeeding winters, and were it not still doubtful when I shall get the time rigorously to reduce the latter. The following data are mostly for the benefit of those who, I hope, will join me in the observation of the variable next winter, or possibly during April and May of the present opposition.

Light-Scale. I have reduced the observations of the second season which were taken for the purpose of forming the light-scale, and likewise re-reduced those of the first season, using only the observations on clear moonless nights; and as these results will not be further changed, except by a revision of the light-scale depending upon several years' observations, or upon better adopted values of the magnitudes upon which it rests. I give them here as the definitive light-scale for each of the two oppositions. Each depends upon the comparisons of about fourteen or fifteen clear moonless nights, the observations being made with opera and field-glasses, except those upon the two or three brightest stars of the scale, which were checked by naked-eye comparisons.

Star	1875.0		M_0	1887-8		Letter	1888-9	
	α	δ		M	L		L	M
	h m s	° ′						
3 *U.A. Antliae*	9 21 9 21 22	—26 2.8 2.6	5.7	5.89	21.1	*c*	21.0	5.90
ε *Pyxidis*	4 39	29 51.3	6.0	6.03	19.7	ε	19.4	6.06
17 *U.A. Antliae*	31 47	31 37.0	6.2	6.11	18.9	*g*	18.9	6.11
16 *U.A. Antliae*	31 23	24 41.3	6.4	6.32	16.8	*j*	17.5	6.25
66 *U.A. Pyxidis*	21 18	28 11.8	6.5	6.43	15.7	*v*	15.7	6.43
52 *U.A. Pyxidis*	3 17	26 15.8	6.5	6.54	14.6	*a*	14.6	6.54
25 *U.A. Antliae*	39 52	29 37.7	6.7	6.71	12.9	*e*	12.6	6.71
58 *U.A. Pyxidis*	8 1	29 9.0	6.9	7.02	9.8	*q*	10.2	6.98
7 *U.A. Antliae*	25 12	28 13.0	–	[7.11]	[8.9]	(*w*)	[8.8]	[7.12]
21 *U.A. Antliae*	36 21	29 41.1	7.0	7.14	8.6	*f*	9.1	7.09
57 *U.A. Pyxidis*	7 0	28 26.1	–	7.18	8.2	*p*	8.2	7.18
Lacaille 3829	20 47	29 29.7	7.6	7.38	6.2	*x*	6.0	7.40
Lacaille 3942	32 1	29 14.4	7.5	7.55	4.5	*k*	4.4	7.56
Lacaille 3751	10 44	28 22.0	7.8	7.65	3.5	*m*	3.2	7.68
Oe. Arg. S. 9784	9 24 37	—28 2.8	7.7	7.78	2.2	*o*	1.8	7.82

The range of light of the variable in this scale is between about (L) 13 to 6, or (M) 6.7 to 7.4, the maxima being generally a little brighter than the star *e*, and the minima a little fainter than *x*. Perhaps a word will not be out of place as to the unusually large number of stars in the light-scale, especially at its brighter end, and as to the observing-letters assigned to the stars.

In my observations on suspected variables, my attention was drawn to this immediate region by the remark of Dr. GOULD, on p. 298 of the *Uranometria Argentina*, as to the star 66 *U.A. Pyxidis*,* of which he says "the magnitude has apparently fluctuated more than once between 6.1 and 6.7 during the course of our observations." This is the star *v* in the above scale, and, during the three seasons of my observations, I have not seen it vary appreciably from its position of about 6.4 in this scale. Two others, for one reason or another, were also suspected, and to them were assigned the letters *w* and *x* in consequence. Thus far all three, *v*, *w*, and *x*, have shown no appreciable variation, and they are given in the above scale, though I have included the values of *w* in brackets, as it has been abandoned entirely the last winter as a comparison-star, on account of its reddish color, but it was used more than any other the first winter, and to some extent during the second. I have thought it necessary to change these letters for others near the head of the alphabet.

The scale was intended to cover the range of all these suspects, and it originally included several others which have been dropped either as unnecessary or as probably variable. I would here mention that the star 65 *U.A. Pyxidis* (6.9 in the *Uran. Argent.*) has apparently fluctuated two or three-tenths of a magnitude, at least, during my observations, and is now generally nearer $7^{M}.2$ than $6^{M}.9$. Also the star 5 *U.A. Antliae* ($7^{M}.0$ in the *U.A.*) I have not seen brighter than $7^{M}.5$ during these three winters, and it apparently varies between about $7^{M}.6$ and $7^{M}.9$ or $8^{M}.0$, perhaps in a short period.

In the middle of the above scale, over the part covered by this variable, the number of stars is none too great for observations in this latitude, where so many of them must be made near the horizon, as a considerable number of stars must be used for safe comparisons in these doubtful situations.

A word as to the method of forming the light-scale. The magnitudes in the column headed M_0 are those first adopted to form it. They rest mostly upon the several Cordoba catalogues, those of the brighter ones almost entirely upon the *U.A.*, though some other more or less reliable catalogues were consulted in assigning these adopted values. The various estimates of the star *p* seemed to indicate that it might be variable, and it was not used. Likewise *w* was not used in the formation of the scale, but its light-value was interpolated in the finished scales directly from the observations.

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* In the *Errata* appended to the *Uranometria Argentina* it is provided that the numeration of the stars nos. 50 to 56 be diminished by one; the no. 49 having been withdrawn from Lac. 3660, since neither component attains the limit $7^{M}.0$. It now appears desirable that the no. 49 be restored, and the subsequent numbers retained as printed. I beg therefore that the erratum, referred to, be stricken out. — G.

The mean adopted magnitude of the seven stars in the upper half of the scale is 6.29, that of the six used in lower half is 7.12. Ten times their difference, or 11.30, was adopted as the difference between the means of the light-values of the same two groups of stars for the standard light-scale, and the difference of the means of the actually observed values for each season was multiplied by the proper factor to reduce it to this. The factor for 1887–8 was 1.161, and for 1888–9 was 1.018, showing that in each case my actual estimates of one light-step were a little greater than 0.1 of a magnitude. This process makes the value of one unit of the above light-scales just 0.1 of a magnitude. A constant was then added all through each, so that the zero of each would correspond to magnitude 8.00. Both scales then satisfy the two conditions $dM = -0.1\ dL$ and $M = 8.00 - 0.1\ L$.

Unless the magnitude of some of these thirteen stars shall appear appreciably to change, it is proposed to reduce the scale for each year to the same standard, and the scales will then be exactly intercomparable, so far as the mean magnitude of the two groups, of seven and six stars, can be considered constant. In the observations of the variable, it is always compared with a brighter and a fainter star, unless considered equal to one, and in reducing the observations the light-value is interpolated in the scale proportional to the observed steps.

Light-Curve. My observations of the first season were insufficient for showing any irregularities in the light-curve, and they were reduced by a curve symmetrical on each side of minimum. This appeared to be of a smooth undulatory character, rising, at first rapidly, and then more slowly towards maximum, the duration above median brightness apparently about twice as long as that below. Little reliance can be placed on this on account of the meagre data. The observations of the two succeeding winters seem to indicate that there is perhaps a lagging or a secondary minimum in the rise from the principal one, and this is a point which I shall endeavor to determine so far as the data at hand will permit, so soon as I can find time to reduce the observations of these two seasons. No curve at any rate would be of sufficient value to publish till these observations can be worked up.

Period. The most probable epoch and period, resulting from the discussion of the first season's observations, are given in the following formula, the time being Greenwich M.T., and referring to the minimum of the light-curve.

$$\begin{aligned} T_m = {} & 1888 \text{ April } 13^d.4971 \pm 0^d.0021 \\ & + (0^d.479\,376 \pm 0^d.000\,049)\, E \\ & - (0^d.000\,009\,11 \pm 0^d.000\,000\,59)\, \tfrac{1}{2}E^2 \end{aligned}$$

After deducing this I was surprised to find, upon approximate trial, that a period about two-thirds as long would apparently satisfy the same observations, and a similar discussion and least-square solution gave the following result.

$$\begin{aligned} T_m = {} & 1888 \text{ April } 13^d.5350 \pm 0^d.0026 \\ & + (0^d.323\,869 \pm 0^d.000\,042)\, E \\ & - (0^d.000\,002\,55 \pm 0^d.000\,000\,30)\, \tfrac{1}{2}E^2 \end{aligned}$$

Comparing them with each other, and having regard to the relative lengths of the periods and the consequent number occurring in the same length of time, it will be seen that the probable errors are slightly in favor of the first solution, and the observations, when plotted according to each formula, look more like a real phenomenon in the case of the $0^d.48$ period.

The observations of the first season, therefore, are insufficient to decide between the two possible periods $0^d.479$ and $0^d.324$; the difficulty arising from the near commensurability of both with the solar day, and the limitation by circumstances to comparisons taken in or near the meridian.

As to the observations of the two succeeding winters, I am not yet entirely sure that they will distinguish between the two. The star is above the horizon of Washington only about 8½ hours, and, except on rare occasions, cannot be well observed for more than six of these. But during the winter of 1888–9 I was able, on at least three nights, to keep up the comparisons for fully 6½ hours, and I feel pretty confident, from a rough inspection of them, that they will show the period of $11^h\ 31^m$ to be at least many times more probable than that of $7^h\ 46^m$, even if they do not demonstrate the latter to be impossible. It may be, however, that observations next winter on other meridians will be necessary to settle this definitely, and I shall hope for cooperation at some of the observatories in the southern hemisphere, where the star can be followed through so much greater an hour-angle.

As to the acceleration-term in the above formulas, while it appears to be necessary to represent the observations for the time covered, I am quite sure that it only indicates a periodic term which the observations were insufficient to determine. In the first formula it would shorten the period in one year from $0^d.479$ to about $0^d.472$. But a rough reduction of some of the best observed minima of the two succeeding winters up to date gives, for the average period for the opposition of 1888–9, $0^d.4802$, and for that of 1889–90, $0^d.4804$; and at the same time there are pretty evident indications of a periodic variation in this, which can only be determined by a rigorous reduction. Still more will this reduction be necessary in order to settle the number of intervening periods between oppositions, and, until I shall have been able to determine something of the character of the periodic terms of the formula, it will be impossible to say whether the observations already accumulated will settle this number of intervening periods.

Still more is it idle at present to speculate as to whether, when three or four oppositions shall have been tied together by a satisfactory formula, this can be extended back for a possible confirmation by the individual observations at Cordoba upon which the magnitude of the star in the *U.A.* (6.9) is based. This must await future investigation.

Washington, 1890 *March* 28.

TWO NEW ASTEROIDS.

A small planet, 13ᴹ, was discovered March 10 by **Charlois** at Nice, in the position

1890 March 10.3467 Gr. M.T. $\alpha = 9^h\ 41^m\ 20^s.5$, $\delta = +8^\circ\ 53'\ 18''$.

A later observation gave for its position

March 20.4238, $9^h\ 36^m\ 8^s.5$, $+9^\circ\ 42'\ 23''$.

Another, also 13ᴹ, was discovered March 20, by **Palisa**, at Vienna, in the position

1890 March 20 Gr. M.T. $\alpha = 12^h\ 35^m\ 6^s.1$, $\delta = +2^\circ\ 7'\ 28''$.

Daily motion $= -1^m\ 40^s$ in α, and $10'$ southward.

These are Nos. 289 and 290. Nos. 282 and 288 have received the names *Clorinda* and *Glauke*, respectively.

COMET *a* 1890.

A comet was discovered by **Brooks**, March 19, in the position

1890 March $19^d\ 16^h$ local time, $\alpha = 21^h\ 9^m$, $\delta = +5^\circ\ 35'$.

Observations were obtained at Cambridge, by Mr. **Wendell**, as follows:

1890 March 21, $21^h\ 42^m\ 6^s$ Gr. M.T.	$\alpha = 21^h\ 9^m\ 34^s.13$,	$\delta = +6^\circ\ 25'\ 30''.3$.
24, 21 11 36	21 10 10 .38,	+7 40 13 .0.

It was about as bright as a star of the tenth magnitude.

Prof. **Holden** telegraphs a position observed at the Lick Observatory by Prof. **Barnard**.

1890 March $24^d.0248$ Gr. M.T. $\alpha = 21^h\ 10^m\ 0^s.9$, $\delta = +7^\circ\ 18'\ 1''$.

From these Cambridge and Lick observations, Rev. **Geo. M. Searle** has computed the following elements, and an ephemeris which is here omitted for want of room. The deviations of the middle place are

$(O-C)\quad \Delta\lambda\cos\beta = +6''$, $\Delta\beta = -1''$

$T = 1890$ June 3.43 Gr. M.T.

$$\left.\begin{aligned}\omega &= 74^\circ\ 1'\\ \Omega &= 320\ \ 46\\ i &= 122\ \ \ 0\end{aligned}\right\}\ \text{M. Eq. 1890.0}$$

$q = 1.7830$

ON PAUL'S SHORT-PERIOD VARIABLE IN *ANTLIA*.

$9^h\ 26^m\ 50^s$; $-28^\circ\ 1'.7$ (1875.0).

By EDWIN F. SAWYER.

At the Cleveland meeting of the American Association for the Advancement of Science (1888), Prof. H. M. **Paul**, of the Washington Observatory, read a paper announcing the variability of this star, No. 12 of *Antlia*, in **Gould's** *Uranometria Argentina*, and giving the results of an investigation of its period. He showed that the period was certainly less than a day, and was probably either about $11^h\ 30^m$, or $7^h\ 15^m$, other hypotheses being excluded by the observation.

I have had the star under observation during the last seven weeks, and am pleased to say that the variability is confirmed in the most unmistakable manner. The range of variation is about 0.6, from 6ᴹ.6 to 7ᴹ.2. The light-curve formed by means of both of the possible periods, above given, assigned by **Paul**, shows a distinct departure from the normal form typical of the ordinary short-period variables, (type of η *Aquilae*), and conforms so nearly with the form of light-curve which is characteristic of the *Algol*-variables that I have little hesitation in assigning it to the latter class. In the chart formed on the assumption of the longer of the two hypotheses as to the period ($0^d.48$), the points representing the individual observations are widely scattered, the departures in many cases exceeding the probable errors. In the similar chart representing the shorter period ($0^d.321$), on the contrary, the points fall into line in a completely satisfactory manner. Indeed, a mere inspection of the two charts gives no escape from the conclusion, not only that the variable is one of the *Algol*-type, but that the period $0^d.321$ is the correct one.

While, from the comparatively small number of observations so far obtained, we cannot infer with much certainty the ratio of the time occupied by the light changes to the duration of the whole period, it is manifestly as small as 0.35, and may be as great as 0.45, or possibly 0.50. Thus this star distinctly bears out the law of relation which Mr. **Chandler** has pointed out as existing between the duration of oscillation and the period in stars of this class, (see *Astr. Jour.* VII, 10); a relation which has been further confirmed by my variable of the *Algol*-type in *Canis Major*, since discovered.

Brighton, Mass., 1890 *Mar.* 30.

EPHEMERIS OF COMET 1889 *V*,

(Continued from page 158,)

BY WILLIAM BELLAMY.

1890 Gr. M.T.	App. α	App. δ	log *r*	log Δ	Br.
	h m s	° '			
Apr. 4.5	3 28 7	+22 47.4	0.3910	0.4964	0.15
5.5	30 4	22 51.5			
6.5	32 1	23 1.6			
7.5	33 58	8.5			
8.5	35 56	15.4	0.3941	0.5032	0.15
9.5	37 53	22.2			
10.5	39 51	28.9			
11.5	41 48	35.6			
12.5	43 46	42.1	0.3973	0.5097	0.14
13.5	45 44	48.6			
Apr. 14.5	3 47 41	+23 55.0			
Apr. 15.5	3 49 39	+24 1.3			
16.5	51 37	7.5	0.4004	0.5160	0.13
17.5	53 35	13.6			
18.5	55 33	19.6			
19.5	57 31	25.5			
20.5	3 59 29	31.4	0.4036	0.5220	0.13
21.5	4 1 27	37.1			
22.5	3 25	42.8			
23.5	5 22	48.4			
Apr. 24.5	4 7 20	+24 53.9	0.4067	0.5278	0.12

NOTE. — The above ephemeris, like those in previous numbers, is based on Mr. CHANDLER's elements of last October (p. 101). Recent observations give the corrections,

Jan. 9	$+4^s$	$+0'.8$
Feb. 15	$+8$	$+1.0$
Mar. 18	$+12$	$+1.1$

thus for the middle of April about $+16^s$ and $+1'.3$. The brightness is decreasing now very slowly, and is only one-quarter less for April than for March. It is therefore probable that the larger instruments can follow the comet through April, and possibly into May. It was observed for position by WENDELL March 18, and by BARNARD March 20; and was "easily seen" at Princeton March 18. If observations can be secured this month, the observed path of the comet since discovery will comprise nearly one-third of the whole ellipse, and they will be of the utmost importance in establishing the orbit previous to its passing through *Jupiter's* system in 1886.—ED.

ELEMENTS AND EPHEMERIS OF COMET *a* 1890 (*BROOKS*),

BY W. W. CAMPBELL.

From observations of the comet made at Cambridge, March 21, and at Ann Arbor, March 26 and 31, I have obtained the following elements and ephemeris. They are necessarily subject to considerable change, since the observed path was short.

For the greater part of the ephemeris I am indebted to Mr. W. J. HUSSEY.

$$T = 1890 \text{ June } 2^d.4415 \text{ Gr. M.T.}$$

$$\left.\begin{aligned} \omega &= 69^\circ\ 55'.71 \\ \Omega &= 320\ \ 34\ .07 \\ i &= 120\ \ 56\ .39 \end{aligned}\right\}\text{Eq. } 1890.0$$

$$\log q = 0.27662$$

Residuals (O—C), $\cos\beta' \Delta\lambda' = -0'.07$, $\Delta\beta = -0'.02$.

EPHEMERIS FOR GREENWICH MEAN MIDNIGHT.

1890	App. α	App. δ	log *r*	log Δ	Br.
	h m s	° '			
April 5	21 11 9	+13 6	0.3061	0.3792	1.5
7	11 3	14 9			
9	10 51	15 14	0.3024	0.3641	1.6
11	10 34	16 21			
13	10 10	17 31	0.2989	0.3484	1.7
15	9 39	18 44			
17	9 0	19 59	0.2957	0.3322	1.9
19	8 12	21 17			
21	7 15	22 37	0.2926	0.3158	2.1
23	6 6	24 1			
25	4 47	25 28	0.2898	0.2991	2.3
27	3 14	26 58			
29	21 1 28	28 30	0.2873	0.2826	2.5
May 1	20 59 27	30 5			
3	20 57 10	+31 46	0.2849	0.2661	2.7

CORRIGENDUM.

No. 210, p. 142, col. 1, line 10 from below, the sentence should not be interrupted. The paragraph should end, and the next begin, after the word "minimum" in line —8.

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CORRIGENDUM.

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SUPPLEMENT TO FIRST EDITION OF THE CATALOGUE OF VARIABLE STARS,

By S. C. CHANDLER.

Since the publication of the above work a number of new variables have been discovered; the variability of some of the suspected cases in the list of such objects appended to that catalogue has been confirmed, either by my own observations or those of others; and many improvements have been made in the elements, some of which I have already published in various places, and others are still unprinted. The time is hardly ripe for a new edition, as there are many calculations and series of observations in progress, the results of which it is extremely desirable should be incorporated. Nevertheless, a partial statement of corrections and additions to date will perhaps be of service, as well for the purpose of fixing the nomenclature, as for providing the means by which the various ephemerides, in the *Vierteljahrsschrift*, the *Annuaire du Bureau des Longitudes*, and the *Observatory* — all of which are now based on this catalogue — can be kept abreast of our knowledge and of the needs of observers. It is therefore thought fitting to publish the present supplement, which is arranged in three tables on the following pages.

I. *List of New Variables supplementary to the Catalogue.* The form of this list is in every respect the same as that of the Catalogue (Vol. VIII, 81–94), to the preface of which, therefore, reference may be made for explanation of its construction.

II. *List of Additions and Corrections to the Elements of the Catalogue.* This comprises the results of such new computations as have been completed up to the present time. In both this and Table I, a dagger is placed in the column next to the last, when the investigation is not original, and the proper authority is accredited in the column of remarks.

III. *List of Stars probably Variable, but awaiting confirmation before assigning* ARGELANDER'S *letters.* This is analogous to the list appended to the original Catalogue, but in a different form. Four stars of that list have now been sufficiently confirmed for the assignment of letters and removal to the Catalogue; namely, 5611 *Z Libræ*, 5903 *Y Scorpii*, 7259 *RS Cygni*, and 7116 *V Delphini*; and they will be found in Table I. Others have been here omitted, and some new candidates have been inserted. It is earnestly hoped that observers will pay especial attention to the objects in this list. In two or three instances my observations are already almost sufficient to warrant transfer to the Catalogue. But caution in this regard can hardly be excessive, and, in answer to any criticism that may easily be made with respect to the exclusion of particular stars from the Catalogue, I can only repeat in justification, what was said in the preface to the first edition, that it should be a paramount object to keep our knowledge clear of confusion, even at the risk of an incomplete statement of it, and that the omission of a star which is really variable is not so injurious as the insertion of one which is not so.

In view of the very great convenience of a reference-number in such a list as this, I have assigned numbers in the first column, on the same system as for the known variables (namely, *one tenth of the right-ascension, expressed in time-seconds, for the equinox 1900.0*), but have inclosed them in parentheses to secure the necessary distinction. No confusion is likely to arise from the use of the same method of number-notation as for the Catalogue-stars. If in any case the star's variability is confirmed, it will merely be necessary to drop the parentheses. Thus, the first star in the list may, until it is confirmed, be referred to as (571) *Ceti*; when it is verified by another observer and takes its place in the Catalogue, it will become 571 W *Ceti*, or, if another variable is meanwhile discovered and confirmed in the constellation, then 571 X *Ceti*.

The suggestion of the numeral notation in [illegible] having met with favor, and having been adopted in various directions, it is hoped that this extension of its application will not be considered injurious to its usefulness; but if any serious objection should be made, it will cheerfully be abandoned, and any evident improvement which may be proposed will be adopted in its place.

While on this subject it is appropriate to say, to avoid misconstruction, that in the proposal of this numerative system it was never intended that the number should be a part of the name of the variable. ARGELANDER'S letter serves that purpose completely. But the permanent reference number has an independent function, a supplementary advantage, and may be used in conjunction with the name or not, according to the convenience of the case.

I. List of New Variables, supplementary to the Catalogue

No.	Sch.	Star	1855.0 R.A.	1855.0 Decl.	Annual Variation		Discoverer	Date	Redness	Magnitude Max.	Magnitude Min.
			h m s	° '	s	'					
1635		R Reticuli	4 32 3	—63 19.8	+0.61	+0.13	Ragoontha Chary	1867		7	<13
3407		S Antliae	9 25 57	—27 59.4	2.63	+0.26	Paul	1888	(0)	6.7	7.3
3409		N Velorum	9 26 49	—56 23.8	1.82	—0.26	Gould	1871	(2)	3.1	4.4
4940		W Hydrae	13 40 51	—27 38.5	3.37	0.30	Sawyer	1888	(7)	7	?
5641		Z Librae	15 38 5	—29 40.1	3.48	0.19	Peters	1879		11	<13
5704		RR Librae	15 48 4	—17 52.6	3.44	0.18	Peters	1885	(3)	8.1	14
5761		Z Scorpii	15 57 29	—21 20.1	3.52	0.17	Peters	1883		9	12?
5903		Y Scorpii	16 21 12	—19 7.1	3.49	0.14	Peters	1876		10?	14
6104		Y Ophiuchi	17 44 52	— 6 6.2	3.21	—0.02	Sawyer	1888		6.2	7.0
6923		Z Sagittarii	19 11 7	—21 11.2	3.56	+0.10	Peters	1888	(2)	8.5	<12
7259		RS Cygni	20 8 7	+38 17.4	2.18	0.18	Espin	1887	(7)	6.5?	9.0<
7416		U Delphini	20 38 50	+17 31.0	2.75	0.21	D'Arrest	1874	(7)	6.4	7.3
7733		Y Capricorni	21 26 27	—14 36.9	+3.29	+0.26	Peters	1884		10?	14?

II. List of Additions and Corrections to the Elements of the Catalogue in Nos. 179, 180.

No.	Star	Greenwich Mean Time Min.	Greenwich Mean Time Max.	Period, etc.	Remarks
		d h m	d h m	d h m s	
320	U Cephei	80 June 23 7 54.65	. . . .	+ 2 11 49 40.70 E	$+0^{s}.00327\,E^{2}$. *Algol*-type
466	U Piscium	79 Oct. 12	80 Jan. 10	+173(?)E	
2100	U Orionis	. . . .	85 Dec. 7	+371 E	
2610	R Canis Maj.	87 Mar. 26 15 18	. . . .	+ 1 3 15 16 E	*Algol*-type
3495	*l* Carinae	71 July 12	71 Aug. 1	+ 31 E	
3825	R Ursae Maj.	52 Dec. 21.2	53 Apr. 7.2	+302.1 E	$+15^{d}\sin(10^{\circ}E+190^{\circ})$
3991	S Leonis	. . . .	60 Dec. 1.0	+190.0 E	$+25^{d}\sin(10^{\circ}E+60^{\circ})$
4521	R Virginis	09 Mar. 24.3	09 June 0.8	+145.47 E	$+20^{d}\sin(9^{\circ}/5\,E+216^{\circ})$ $+4.8^{d}\sin(45^{\circ}/8\,E+34.$[illegible]$^{\circ})$
4557	S Ursae Maj.	60 Feb. 24.5	60 June 11.0	+226.5 E	$+40^{d}\sin(5^{\circ}E+205^{\circ})$
4805	W Virginis	69 Apr. 17.478	69 Apr. 25.678	+ 17.26987 E †	Yendell's elements
5037	RR Virginis	. . . .	79 May 13	+217 E	
5484	U Coronae	70 Mar. 25 10 38.5	. . . .	+ 3 10 51 12.4 E	$-0^{s}.0018\,E^{2}$. *Algol*-type
5501	S Serpentis	. . . .	28 Apr. 19.0	+364.8 E	$+50^{d}\sin(6^{\circ}E+5^{\circ})$
5583	X Librae	. . . .	78 Aug. 6	+295 E †	Peters's elements
5593	W Librae	. . . .	78 May 27	+206 E	
5617	U Librae	. . . .	73 May 29	+230 E	
5677	R Serpentis	. . . .	27 May 7.0	+357.6 E	$+48^{d}\sin(\frac{60}{11}E+8^{\circ})$
5776	X Scorpii	. . . .	76 Apr. 19	+199 E	
6044	S Herculis	56 Mar. 27	56 Aug. 30.0	+309.2 E	$+55^{d}\sin(7^{\circ}.5\,E+100^{\circ})$ $+18^{d}\sin(15^{\circ}.0\,E+61^{\circ})$
6088	V Herculis	. . . .	. . . .	. . . .	My very numerous observations indicate that the star is not variable.
6472	W Sagittarii	66 Sept. 1.45	66 Sept 4.45	+ 7.59460 E	
6512	T Herculis	67 Dec. 22.3	68 Mar. 9.3	+164.75 E	$+6^{d}.5\sin(7^{\circ}.5\,E+52^{\circ}.5)$
6758	β Lyrae	55 Jan. 6 14 28.7	. . . .	+ 12 21 46 58.3 E †	$+0.4217^{s}\,E^{2}-0.00007^{s}\,E^{2}$. Reed's elements. Secondary minimum about midway.
7120	χ Cygni	1762 Dec. 14.0	1763 June 3.5	+406.02 E +0.0075 E²	$+25^{d}\sin(5^{\circ}E+272^{\circ})$
7220	S Cygni	. . . .	65 July 9.0	+322.2 E	Periodic irregularities in per'd
7252	W Capricorni	. . . .	72 June 27	+209 E	
7437	X Cygni	86 Oct. 3 13 20	86 Oct. 10 10 56.3	+ 16 9 36 51 E †	Yendell's elements. Bright and faint maxima and minima, but not regularly altern'g
7488	Y Cygni	86 Dec. 9 11 14.5	. . . .	+ 1 11 57 18 E	*Algol*-type. Large periodical anomalies in period.
7560	R Vulpeculae	65 July 14.3	65 Sept. 18.5	+136.93 E	$+22^{d}\sin(4^{\circ}.8\,E+72^{\circ})$
7571	V Capricorni	. . . .	67 Aug. 12	+157.3 E	
7577	X Capricorni	. . . .	67 Aug. 9	+218 E	
7907	U Aquarii	. . . .	75 Aug. 4	+258(?) E	
8153	R Lacertae	. . . .	56 Oct. 23	+300.6 E †	Deichmüller's elements
8597	V Ceti	. . . .	79 Sept. 29	+256 E	

IN Nos. 179, 180 OF THE *Astronomical Journal.*

Greenwich Mean Time		Period, etc.	Remarks	1900.0		No.
Min.	Max.			R.A.	Decl.	
d h m	d h m s	d h m s		h m	° ′	
. . . .	64 Feb. 1	+281 E		4 32.5	—63 14	1635
88 Apr. 13 12 55.4	. . . .	+ 0 7 46 48.0 E 4.25?	*Algol*-type	9 27.9	—28 11	3407
. . . .	. . . .			9 28.2	—56 36	3409
. . . .	89 March	+370(?) E	Sawyer's estimated period	13 43.1	—27 52	4940
. . . .	78 May 4	+295 E		15 40.7	—20 19	5644
. . . .	85 June 17	+277.0 E		15 50.6	—18 1	5704
. . . .	73 June 4	+365 E		16 0.1	—21 28	5761
. . . .	76 June 26	+359 E		16 23.8	—19 13	5903
82 Aug. 26.85	82 Sept. 3.70	+ 17.14 E †	Sawyer's elements	17 47.3	— 6 7	6404
. . . .	. . . .	. . . .		19 13.8	—21 6	6923
. . . .	. . . .	. . . .		20 9.8	+38 25	7259
. . . .	. . . .	. . . .		20 40.9	+17 41	7146
. . . .	85 Sept. 5	+206(?)E	Period perhaps 406^d	21 28.9	—14 25	7733

III. LIST OF STARS PROBABLY VARIABLE, BUT AWAITING CONFIRMATION BEFORE ASSIGNING ARGELANDER'S LETTERS.

No.	Star	1855.0		Remarks
		R.A.	Decl.	
		h m s	° ′	
(571)	—Ceti	1 33 0	— 7 21.6	Safarik thinks variable, 8.4 to 9.2; period probably longer than four months.
(1367)	—Tauri	3 45 26	+ 7 20.6	Gould thinks certainly variable, 6.8 to 8.0. My observations favor, but not yet decisive.
(1745)	—Eridani	4 48 48	—16 39.3	Gould's *R Eridani.* Sawyer's observations so far show no change.
(1772)	—Eridani	4 53 11	—12 45.1	Gould's *S Eridani.* Sawyer's observations so far show no change.
(1805)	—Orionis	4 58 25	+ 3 54.1	Boss thinks variable, 9 to 11.5, on strong evidence.
(1948)	F.31 Orionis	5 22 22	— 1 14.7	Gould says appears variable, 4¾ to 6. Gore thinks his observations confirm.
(2258)	—Aurigae	6 12 51	+47 43.5	Espin suggests variability. My observations favor, but not yet decisive.
(2305)	—Lyncis	6 20 14	+58 50.6	Kreutz suspects variability. My observations favor.
(2741)	—Puppis	7 35 15	—31 19.6	Gould's *R Puppis.* Neither Sawyer's observations nor mine yet confirm it.
(2788)	—Puppis	7 43 11	—40 17.5	Gould's *T Puppis.*
(2903)	—Cancri	8 1 16	+19 50.0	Peters's *W Cancri.* Neither Parkhurst's observations nor mine yet confirm it.
(3614)	—Velorum	10 0 42	—51 29.0	Gould's *R Velorum.*
(3908)	—Carinae	10 19 30	—59 14.8	Gould's *T Carinae.* Upton's observations favor, but limits are very slight, and further confirmation desirable.
(4195)	β Corvi	12 26 47	—22 35.7	Sawyer's observations seem to show clearly the variability, but further confirmation desirable.
(5076)	—Bootis	14 3 55	+20 30.1	Pogson finds variable, 8.7 to 12.
(5402)	—Triang. austr.	14 56 20	—68 9.1	Gould's *T Triang. austr.* Limits only 7.0 to 7.4; period about one day
(5626)	—Librae	15 35 17	—10 27.7	Weisse thinks variable, 7.0 to 8.8; period about four months. My observations favor strongly.
(5952)	F.33 Herculis	16 29 50	+ 7 23.3	I think variable, 7.0 to 7.8; period about three weeks. Yendell's observations favor.
(6470)	—Ophiuchi	17 56 7	+ 2 30.5	Safarik thinks variable, 8.2 to 8.8; period 58^d.2
(6546)	—Sagittarii	18 8 0	—34 9.1	Gould thinks variable, 6.2 to 7.4.
(6913)	—Sagittae	19 15 13	+17 23.1	Espin suggests variability. My observations favor, but do not certainly confirm.
(7010)	—Sagittae	19 26 15	+17 26.0	I think observation will ultimately establish variability. See *A.J.* VIII, 93, and *Science Observer,* IV, Nos. 13, 14.
(7302)	—Capricorni	20 14 28	—16 28.2	Pogson finds variable, 10.4 to <12
(8528)	F.19 Piscium	23 39 0	+ 2 10.8	Gould suspects variability. Espin's and Gore's observations favor, mine do not, allowing for subjective effects of strong red color
(8594)	—Cephei	23 49 44	+82 23.0	I think variable, 6.4 to 7.1, period long or irregular. Yendell's observations favor.
(8617)	—Cassiopeae	23 53 54	+59 33.1	Secchi suspected variability, and my observations independently suggested it, but later I inclined to doubt.

ON THE VARIABLE STAR *X CYGNI*,

BY PAUL S. YENDELL.

The observation of this star was resumed 1889 April 25, and kept up as continuously as possible until 1890 Jan. 24, when the star became too low at dark for useful observation. In all, 148 observations were secured, from which the following maxima and minima have been deduced by the usual method with the single light-curve.

The residuals in the column O—C are derived from comparison with the elements published in this Journal, Vol. VIII, p. 177, and correspond with the column $\overset{Y}{O-C}$ in the table there given.

E	Maxima	O—C d	w	Minima	O—C d	w
58	'89 May 17.8	—1.0	½			
59	June 3.9	—0.2	1	'89 May 26.2	—2.0	1
60	20.0	—0.5	1			
61	July 5.9	—1.0	1	June 30.3	+0.3	1
62	21.8	—1.5	1	July 14.7	—1.7	1
63	Aug. 7.8	—0.9	1	31.4	—1.4	1
64	24.5	—0.6	1	Aug. 17.4	—0.8	1
65				Sept. 2.0	—1.6	½
66	Sept. 27.5	+0.6	1	21.5	+1.5	1
67	Oct. 12.8	+0.5	1	Oct. 4.5	—2.0	1
68				21.2	—1.6	1
69	Nov. 14.2	—0.9	1	Nov. 7.1	—1.1	1
70	30.3	—0.8	1	23.6	—1.0	1
71	Dec. 18.0	+0.1	1	Dec. 11.4	+0.4	1
72	'90 Jan. 2.0	—1.3	1	24.4	—3.0	½
73	19.2	—0.5	1	'90 Jan. 13.7	+0.9	1

By the use of a mean light-curve made from all the observations, the following maxima and minima have been deduced, in those cases where the usual method was unavailable, on account of breaks in the series caused by unfavorable weather; but no weight is assigned them, and they have not been employed in the discussion of the observations from which the results given below are drawn, as, from the character of the star's variations, any mean light-curve must be, as stated in the paper in Vol. VIII before referred to, of very questionable value.

	Maxima		Minima
57	1889 May 1.16	60	1889 June 12.3
65	Sept. 8.7	65	Sept. 2.1

Mr. J. E. Gore, of Beltra, Ballisodare, Ireland. has very kindly sent me in manuscript, a series of observations, 32 in number, extending from 1889 Sept. 4 to 1890 Jan. 13; from which I have deduced, by the single light-curve method, the following times of maxima and minima.

E	Maxima	Minima
65	1889 Sept. 8.8	
67	Oct. 12.8	
68	29.8	1889 Oct. 23.3
69	Nov. 16.5	
70		Nov. 25.5
71	Dec. 18.0	Dec. 11.4

From the residuals O—C in the first table of maxima given above, used in connection with those given in the paper already referred to, we find, by the application of the method of least-squares, the following corrections:

To the epoch, $+0^{d}.117 \pm 0^{d}.18$
" period, -0.0131 ± 0.005

The probable error of a single determination of maximum, of weight unity, is $\pm 0^{d}.21$.

From the residuals in the column O—C in the corresponding tables of minima, are deduced, by the same process, the following corrections:

To the epoch $+0^{d}.329 \pm 0^{d}.368$
" period -0.017 ± 0.007

The probable error of a single determination of minimum, of weight unity, is $\pm 0^{d}.838$.

The fact, that the correction to the epoch of minimum is exceeded by its probable error, goes to indicate that this correction is not a real one; a sensible correction to the period, however, is shown.

The interesting question of the periodical character of the irregularity of the star's period still remains unsettled; the residuals of both observed maxima and minima, though materially reduced by the application of the above corrections to the elements, still give a suggestion of such a fluctuation; but at least one or two years' further observations are necessary in order to make any approach to a decision.

The characteristic peculiarities of the light-curve, noted in the last year's paper, are fully confirmed by the last season's observations; in addition, a step in the rising curve, about half-way from the minimum to the maximum, is strongly indicated in many of the epochs; in one or two of them it shows quite the character of a subsidiary maximum.

The fluctuation in the range of the light-curve has been carefully watched, and the light-values at maximum and minimum, on the same scale as those published in Vol. VIII, page 178, are given in the subjoined table, which is a continuation of the former.

	Maxima	Minima		Maxima	Minima
E	L	L	E	L	L
58	12.0		66	12.0	7.7
59	14.0	6.7	67	12.0	6.0
60	13.0		68		5.7
61	14.5	5.7	69	11.0	5.3
62	13.0	8.0	70	11.5	3.5
63	14.0	7.7	71	12.0	4.5
64	13.5	7.5	72	11.5	4.5
65		7.5	73	11.5	5.5

At the beginning of the season's observations, a strong suspicion was entertained that this fluctuation was in great part due to atmospheric absorption, as the star was observed at changing altitudes through the season; this, however, seems to be definitely disposed of by the fact that the highest observed maximum light was noted at a time when the star, at the time of observation, was still rather low in the northeast; while the lowest observed lights at both maximum and minimum phases were observed when the star was high overhead, or but comparatively little past the zenith; the phenomenon, therefore, appears to be a real one.

The periodic character of this fluctuation I do not regard as distinctly shown: but on the other hand, the very interesting fact is apparent, that, generally speaking, the star's whole light-curve may be said to move up and down by some 3½ steps, or about 0.4 of a magnitude: a bright maximum corresponding to a bright minimum, and *vice versa*. The suspicion of a connection between this irregularity and that of the length of the period, has not been borne out by the observations.

Dorchester, Mass., 1890 *March* 2.

OBSERVATIONS OF *S ANTLIAE*,

BY E. F. SAWYER.

The following table, containing the observations of this star in detail was omitted from the article in the last number of the Journal, for want of space.

The brightness is expressed in the light-scale indicated in the last column of the table of comparison-stars below:

Name	1875.0 α	1875.0 δ	U.A.	S.	L.
66 *U.A. Pyxidis*	9h 21m 18s	−28° 14′.8	6.5M	6.5M	10.0
7 *U.A. Antliae*	25 12	28 13.0	7.0	7.0	5.0
5 *U.A. Antliae*	24 29	27 41.7	7.0	7.5	0.0

CAMBRIDGE MEAN TIME.

1890	L	1890	L	1890	L	1890	L	1890	L	1890	L
Feb. 13d.448	9.0	Feb. 22d.448	3.0	Mar. 17d.437	4.0	Mar. 19d.417	5.0	Mar. 24d.322	7.0	Mar. 30.400	6.5
15.525	9.0	.483	7.0	18.308	8.0	21.333	3.5	.334	7.5	.403	6.0
16.424	9.0	Mar. 9.358	2.0	.344	7.5	21.344	3.0	.364	8.0	.420	4.5
.448	9.0	.384	4.0	.375	7.0	.361	3.0	.396	8.5	.448	5.0
20.437	7.0	.417	7.0	.392	4.0	.382	5.0	26.426	8.0	Apr. 5.321	6.0
.451	4.0	.437	8.0	.403	2.5	.399	7.0	.448	7.5	.347	8.0
.465	3.0	12.431	9.0	.417	2.5	.420	8.5	.462	7.0	.372	9.0
21.413	5.0	16.437	5.0	.428	3.0	.431	9.0	27.351	8.0	.448	9.0
.448	3.0	17.305	8.5	.448	3.5	23.417	9.0	.480	5.0	6.400	4.0
.465	3.0	.333	9.0	.458	4.0	.448	9.0	30.323	8.5	7.322	9.0
.476	3.0	.375	7.0	.465	6.5	.489	9.0	.363	8.0	7.448	7.0
22.410	3.0	17.424	4.0	18.479	7.5	24.312	6.5	30.383	7.5		

FILAR-MICROMETER OBSERVATIONS OF COMET *a* 1890 (*BROOKS, March 19*).

MADE WITH THE 12-INCH EQUATORIAL OF THE LICK OBSERVATORY.

BY E. E. BARNARD.

1890 Mt. Hamilton M.T.	✱	No. Comp.	☌ − ✱ Δα	☌ − ✱ Δδ	☌'s apparent α	☌'s apparent δ	log pΔ for α	log pΔ for δ
Mar. 23d 16h 29m 10s	1	16 , 6	+0m 27s.27	+1′ 12″.1	21h 10m 0s.88	+7° 18′ 0″.8	n9.642	0.695
26 16 28 0	2	12 , 6	−1 24.70	+2 32.8	21 10 31.22	+8 35 13.2	n9.636	0.686

Mean Places for 1890.0 of Comparison-Stars.

✱	α	Red. to app. place	δ	Red. to app. place	Authority
1	21h 9m 31s.83	−1s.22	+7° 11′ 0″.6	−12″.1	Weisse's Bessel XXI, 152
2	21 11 57.06	−1.14	+8 32 52.7	−12.3	Weisse's Bessel XXI, 216

March 23. Comet about 11 mag. A 10M nucleus in the north part of the nebulosity; a faint, short, fan-shaped tail or diffusion, extending *due south*. This observation obtained by one night's break in our continuous cloudy weather. The clouds have again closed in, preventing any more observations for some time.

Mt. Hamilton, 1890 *March* 26.

QUESTIONS OF PRIORITY.

BY WILLIAM FERREL.

It is well known that there is a discrepance between the times of the computed and observed phenomena of certain ancient eclipses, which indicates that there has been a retardation of the earth's rotation. A plausible explanation of such a retardation is, that it is due to the effect of friction upon the tidal wave. The first suggestion of this explanation is usually attributed to DELAUNAY. In THOMSON and TAIT's Natural Philosophy it is stated that "about the beginning of 1866 DELAUNAY suggested that the true explanation of the discrepance might be a retardation of the earth's rotation by tidal friction." DELAUNAY's note on this subject was communicated to the Academy at Paris on Dec. 11, 1865 (*Comptes Rendus*, Vol. CI, p. 1023). My "Note on the Influence of the Tides in Causing an Apparent Acceleration of the Moon's Mean Motion" was read before the American Academy of Arts and Sciences on Dec. 13, 1864 (*Proc.* Vol. VI, pp. 379–383). In this note it was shown that upon the hypothesis of only a very moderate displacement of the vertex of the tidal wave by friction, the resulting amount of retardation of the earth's rotation would furnish an explanation of the discrepance between the computation and observation of the ancient eclipses.

The writer also claims that the first suggestion that the cause of the exact equality between the time of the moon's rotation on its orbit and on its axis is due to the effect of the attracting forces upon the lunar tides, was given in his paper "On the Effect of the Sun and Moon upon the Rotary Motion of the Earth" (*Astr. Jour.*, 1853, III, pp. 138–142).

OBSERVATIONS OF COMET *a* 1890 (*BROOKS*),

MADE WITH THE 6-INCH EQUATORIAL OF THE DETROIT OBSERVATORY,

BY W. W. CAMPBELL.

1890 Greenwich M.T.	∗	No. Comp.	☄ — ∗		☄'s apparent		log pΔ	
			Δα	Δδ	α	δ	for α	for δ
d h m s			m s	′ ″	h m s	° ′ ″		
Mar. 22 21 59 37	1	5 , 3	+1 47.07	+4 33.6	21 9 46.55	+ 6 50 16.8	*n*9.618	0.750
26 21 39 3	2	8 , 7	—2 41.50	+2 9.6	21 10 29.99	+ 8 31 51.8	*n*9.623	0.745
22 19 43	3	5	—1 25.67		21 10 30.31		*n*9.590	
30 21 19 57	4	12 , 11	+0 17.85	+6 49.0	21 10 58.77	+10 20 18.1	*n*9.627	0.738
21 59 53	5	5		+0 59.9		+10 21 4.4		0.722
31 21 30 34	6	9 , 8	+3 1.93	+3 23.3	21 11 3.09	+10 48 42.0	*n*9.619	0.723
21 30 34	7	9	+2 10.14		21 11 3.54		*n*9.619	
21 30 31	8	9 , 5	+0 41.33	+4 42.6	21 11 3.09	+10 48 40.6	*n*9.619	0.723

Mean Places for 1890.0 of Comparison-Stars.

∗	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	21 8 0.72	—1.24	+ 6 45 55.3	—12.1	Schjellerup 8563
2	21 13 12.65	—1.16	+ 8 29 54.5	—12.3	Glasgow 5414
3	21 11 57.14	—1.16	+ 8 32 53.6	—12.3	½(W.B$_1$ XXI 216 + Lam$_2$ 5886)
4	21 10 41.97	—1.05	+10 13 41.8	—12.7	Glasgow 5402
5	21 10 18.75	—1.05	+10 20 17.2	—12.7	½(W.B$_1$ XXI 174 + Schj. 8585)
6	21 8 2.19	—1.03	+10 45 31.4	—12.7	Glasgow 5387
7	21 8 54.43	—1.03	+10 43 53.8	—12.7	W.B$_1$ XXI 137
8	21 10 22.79	—1.03	+10 44 10.7	—12.7	½(Lam$_4$ 2529 + Bonn 10°4197)

March 22, Frequent interference from clouds.

March 26, 30. Further observations prevented by clouds.

ELEMENTS OF PAUL'S *ALGOL*-TYPE VARIABLE, *S ANTLIAE*.

BY S. C. CHANDLER.

My observations accord entirely with Mr. SAWYER's in establishing this star as of the *Algol*-type. From a discussion of his observations on p. 189 I get five minima, while my own give three; besides one last year, which, although very imperfect, is useful in fixing the enumeration of the periods back to PAUL's epoch. I thus find the elements

$$1888 \text{ April } 13^d\ 12^h\ 55^m.4 \text{ (Greenw.) } +0^d\ 7^h\ 46^m\ 48^s.0\ E$$

the comparison of which with the observations follows.

The star remains at maximum brightness about $4^h\ 30^m$; the decrease and increase occupying each about $1^h\ 40^m$. The minima can be very sharply determined, under good conditions, with a probable uncertainty of three or four minutes.

Cambridge, 1890 *April* 6.

E	Observed Min. Camb. M.T.	Red. to ⊙	O—C	p	Obs.
	d h m	m	m		
0	1888 April 13 8 5.9	+5.0	0.0	–	P
1157	1889 April 23 9 0.0:	+3.4	—35. :	1	C
2095	1890 Feb. 21 11 0.0	+6.2	—10.7	5	S
2166	Mar. 16 11 38.9	+5.9	+ 5.1	5	S
2172	18 10 9.4	+5.8	— 5 1	5	S
2181	21 8 10.2	+5.7	— 5.6	5	S
2197	26 12 48.0	+5.4	+ 2.9	4	S
2209	30 10 18.2	+5.2	+11.3	2	C
2215	April 1 8 44.0	+5.1	— 3.8	5	C
2218	1890 April 2 8 16.5	+5.0	+ 8.2	2	C

OBSERVATIONS OF COMET 1889 *I*,

MADE AT THE HALSTED OBSERVATORY, PRINCETON, WITH THE 23-INCH EQUATORIAL AND SQUARE-BAR MICROMETER

BY D. C. MILLER.

[Communicated by Professor YOUNG.]

Eastern Standard Time = Gr. M.T. —5ʰ		*	No. Comp.	☄ — *		☄'s apparent		log pΔ	
				Δα	Δδ	α	δ	for α	for δ
1890	h m s			m s	′ ″	h m s	° ′ ″		
Feb. 10	7 56 40	17	10	+0 53.30	— 7 42.8	1 48 10.38	+14 45 33.8	9.570	0.660
12	7 55 21	18	6	—0 43.87	+ 4 53.0			9.576	0.622
	7 56 4	19	5	—0 14.88	+ 1 56.2			9.577	0.618
13	7 49 47	20	16	+0 54.51	— 6 8.5	1 53 33.87	+15 17 24.6	9.571	0.629
14	7 53 58	20	6	+2 43.35	+ 4 23.8	1 55 22.70	+15 27 56.8	9.580	0.622
15	7 44 23	20	7	+4 31.81	+11 42.0	1 57 11.16	+15 38 15.0	9.570	0.611
Mar. 8	7 51 27	21	6	—0 49.33	+ 8 15.7	2 36 14.43	+19 5 48.1	9.635	0.651

Mean Places for 1889.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
17	1 47 18.29	—1.21	+14 53 21.9	—5.3	Weisse's Bessel (1) I, 811
20	1 52 40.57	—1.22	+15 23 38.3	—5.3	½(Yarnall 936 + Paris 2448)
21	2 37 5.10	—1.34	+18 57 37.0	—4.6	Weisse's Bessel (2) II, 854

NOTES.

Feb. 10, 12, 13 and 15. Seeing good: comet easily seen, with nucleus and tail.

Feb. 12. By an oversight two stars were used which cannot be identified; their approximate places for 1890 are:

No. 18, $\alpha = 1^h 52^m 31^s$, $\delta = +15^\circ 2'.0$,
No. 19, $\alpha = 1\ 52\ \ 2$, $\delta = +15\ 5.0$.

At the time of observation one of them was supposed to be DM. 14°316.

Feb. 14. Seeing poor.

March 8. Moonlight stopped the observations. Comet still easily seen, but without nucleus; it was a mere diffuse patch of light, difficult to observe with precision.

March 18. The comet was seen, but mist stopped the observation after a single unsatisfactory comparison.

OBSERVATIONS OF COMET 1886 *VII*,

MADE AT THE HARVARD COLLEGE OBSERVATORY.

BY O. C. WENDELL, ASSISTANT.

[Communicated by Professor EDWARD C. PICKERING, Director.]

1886–87 Cambridge M.T.		*	No. Comp.	☄ — *		☄'s apparent		log pΔ	
				Δα	Δδ	α	δ	for α	for δ
	h m s			m s	′ ″	h m s	° ′ ″		
Oct. 19	6 56 28	1	7	+0 17.97	—10 27.7	18 8 56.87	—26 37 1.5	9.4[illegible]8	0.878
20	6 35 22	2	7	—0 0.73	—13 43.2	18 12 20.11	—26 35 57.8	9.450	0.887
Jan. 3	8 51 50	3	5	—4 11.59	— 1 10.9	0 3 48.13	+ 0 45 6.2	9.552	0.770

Mean Places for 1886.0 and 1887.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	18 8 37.19	+1.71	—26 26 11.4	+7.6	Cordoba Zone-Catal. XVIII 642
2	18 12 19.46	+1.71	—26 22 2.2	+7.6	" " " XVIII 766
3	0 8 0.74	—0.72	+ 0 46 22.2	—5.1	Weisse's Bessel, O, 99

OBSERVATIONS OF COMET 1889 *V*,

MADE AT THE HAVERFORD COLLEGE OBSERVATORY,

BY D. P. HIBBERD AND F. P. LEAVENWORTH.

1889-90 Haverford M.T.	✱	No. Comp.	☄ — ✱ $\Delta\alpha$	☄ — ✱ $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ	Obs.
d h m s			m s	′ ″	h m s	° ′ ″			
Nov. 23 8 30 17	1	11 , 7	—0 21 15	+3 38.2	23 53 57.15	+ 0 32 9.2	8.886	0.748	H
Jan. 22 8 33 18	2	5	—0 19.24	—3 8.6	1 15 7.71	+11 17 48.4	9.560	0.657	L

Mean Places for 1889.0 and 1890.0 of Comparison-Stars.

✱	α	Red. to app. place	δ	Red. to App. place.	Authority
	h m s	s	° ′ ″	″	
1	23 51 19.11	+2.19	+ 0 28 16.4	+14.6	Yarnall (F) 10895
2	1 15 28.03	—1.08	+11 21 2.4	— 5.4	Yarnall (F) 680

Comet very faint. The first observation was made by D. P. HIBBERD with filar micrometer; the second by F. P. LEAVENWORTH, with square-bar micrometer.

EPHEMERIS OF VARIABLES OF THE *ALGOL*-TYPE.

Approximate Greenwich M.T., 1890.

	May d h		May d h		May d h		May d h		May d h
S Antliae	1 12	*U* Coronae	5 17	*U* Coronae	12 14	*S* Antliae	18 9	δ Librae	25 12
S Antliae	2 12	*Y* Cygni	5 18	*S* Antliae	13 12	δ Librae	18 13	*U* Ophiuchi	25 13
S Cancri	2 11	*S* Antliae	6 9	*R* Can. Maj.	13 13	*U* Coronae	19 12	*U* Coronae	26 10
Y Cygni	2 18	δ Librae	6 21	*U* Ophiuchi	13 19	*U* Cephei	19 12	*Y* Cygni	26 17
R Can. Maj.	3 7	*Y* Cygni	8 18	δ Librae	13 21	*U* Ophiuchi	19 16	δ Librae	27 20
S Antliae	3 11	*U* Ophiuchi	8 19	*S* Antliae	14 11	*R* Can. Maj.	20 9	*R* Can. Maj.	28 8
U Ophiuchi	3 18	*U* Cephei	9 13	*U* Cephei	14 12	*U* Ophiuchi	20 12	*U* Cephei	29 11
S Antliae	4 10	*U* Ophiuchi	9 15	*U* Ophiuchi	14 15	*Y* Cygni	20 17	*R* Can. Maj.	29 11
R Can. Maj.	4 11	*U* Ophiuchi	10 11	*Y* Cygni	14 17	δ Librae	20 20	*Y* Cygni	29 17
U Cephei	4 13	*R* Can. Maj.	11 7	*U* Ophiuchi	15 11	*R* Can. Maj.	21 12	*U* Ophiuchi	29 18
U Ophiuchi	4 14	δ Librae	11 13	*S* Antliae	15 11	*S* Cancri	21 14	*U* Coronae	29 20
δ Librae	4 14	*Y* Cygni	11 18	*S* Antliae	16 10	*Y* Cygni	23 17	*U* Ophiuchi	30 14
S Antliae	5 9	*S* Cancri	12 2	*S* Antliae	17 9	*U* Cephei	24 12	*S* Cancri	31 1
R Can. Maj.	5 14	*R* Can. Maj.	12 10	*Y* Cygni	17 17	*U* Ophiuchi	24 17	*U* Ophiuchi	31 10

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INVESTIGATION OF ERRORS IN LACAILLE'S *COELUM AUSTRALE STELLIFERUM,*

BY B. A. GOULD.

III.

Catalogue-position.			C. A.		Arg. Gen. Catal. for Equinox 1750.0			
No.	R.A.	N.P.D.			No.	Mag	α	δ
	h m s	° ′ ″	page				h m s	° ′ ″
4900	11 36 49.0	140 4 11	73	Assume ingress at 11 37 52 instead of 11 38 7, which gives the position 11^h 36^m 41^s.7, 50 1′ 47″	16141	8¼	11 36 42.0	50 1 11
4916	11 39 10.3	138 10 0	72	Assume ingress at 11 39 15 instead of 11 38 15, which gives the position 11^h 39^m 41^s.3, 48 0′ 8″	16201	8	11 39 39.8	48 0 40
4930	11 41 40.7	124 32 46	109	Assume ingress at 11 40 11 instead of 11 40 26, which gives the position 11^h 41^m 32^s.9, 34 35′ 48″	16242	8½	11 41 34.7	34 36 4
A 4955	11 45 33.8	116 15 14	129	Cannot be reconciled without changes in both moments. Assume ingress at 11 43 49 instead of 11 44 4, and egress at 11 47 11 instead of 11 47 16. Then we have the position 11^h 45^m 23^s.7, 26° 17′ 57″	16337	7¾	11 45 24.2	26 17 39
4964	11 46 27.5	124 4 20	109	Assume ingress at 11 47 5 instead of 11 46 20, which gives the position 11^h 46^m 50^s.6, 33 55′ 3″	16375	7½	11 46 51.2	33 55 0
4968	11 46 45.5	166 8 4	17	Reducing for the upper part of the reticule, we have the position 11^h 46^m 42^s.3, 76 25′ 14″	16358	6¾	11 46 36.4	76 25 59
5011	11 53 4.2	142 49 12	67	Assume ingress at 11 51 52 instead of 11 54 32, which gives the position 11^h 53^m 13^s.9 52 52′ 14″ — being that of no. 5014.	16514	7¾	11 53 13.6	52 51 57
5022	11 54 4.0	121 28 57	115	Assume ingress at 11 54 58 instead of 11 53 58, which gives the position 11^h 54^m 31^s.8, 31 16′ 14″	16553	8	11 54 34.1	31 16 8
5052	11 58 12.8	132 58 37	89	Assume ingress at 11 56 56 instead of 11 56 26, which gives the position 11^h 58^m 28^s.3, 42 53′ 14″	16641	7	11 58 32.2	42 53 21
A 5074	12 1 47.2	117 39 18	129	Assume ingress at 12 1 11 instead of 12 0 21, which gives the position 12^h 2^m 11^s.6, 27 50′ 26″,	16731	6¾	12 2 11.8	27 50 41
5096	12 6 33.3	177 8 45	1	Both moments appear to be recorded about 6^m too late. See no. 3274, observed on the same night.	16709	6¼	12 0 4.1	87 1 25
5117	12 8 54.5	127 8 46	102	Assume ingress at 12 6 15 instead of 12 5 15, which gives the position 12^h 9^m 9^s.9, 37 2′ 51″	16855	8	12 9 9.3	37 3 41
5169	12 16 8.9	144 42 1	61	The stars came rapidly here and four successive egresses are seriously wrong. Assume egress at 12 19 0 instead of 12 21 10, which gives the position 12^h 15^m 2^s.8 55 1′ 10″	16992	6¼	12 15 2.5	55 0 49
5175	12 16 49.0	144 59 8	61	Assume egress at 12 19 53 instead of 12 20 53, which gives the position 12^h 16^m 18^s.5, 55 7′ 52″	17011	6	12 16 16.7	55 8 24
5178	12 17 10.5	145 7 18	61	The egress (recorded 2^m too early) is interchanged with that of no. 5190. Correcting, we have the position 12^h 18^m 30^s.3, 54 44′ 15″	17078	7	12 18 27.8	54 44 45
A 5179	12 17 16.3	119 30 16	123	Assume ingress at 12 16 45 instead of 12 15 45, which gives the position 12^h 17^m 46^s.9, 29 17′ 24″	17050	8½	12 17 46.9	29 17 33
A 5187	12 17 56.9	119 48 50	123	Assume ingress at 12 16 43 instead of 12 15 43, which gives the position 12^h 18^m 27^s.4, 29 36′ 1″	17071	7	12 18 28.5	29 35 51
5190	12 18 43.1	144 48 3	61	Assuming egress of no. 5178 increased by 2^m, we have the position 12^h 18^m 24^s.3, 54 53′ 34″. Were the increase by 1^m 55^s we should have the position 12^h 18^m 21^s.8, 54 54′ 18″	17074	7¾	12 18 20.6	54 54 15

Catalogue-position.			C. A.		Arg. Gen. Catal. for Equinox 1750.0			
No.	R.A.	N.P.D.			No.	Mag	α	δ
	h m s	° ′ ″	page				h m s	° ′ ″
A 5225	12 24 31.4	115 45 35	129	See Argelander's note, Bonn Obs. VII, p. 128; *d Hydrae.*	17185	5½	12 24 31.1	25 45 22
A 5232	12 26 38.0	118 19 15	129	Assume ingress at 12 26 34 instead of 12 26 44, which gives the position $12^{h}\ 26^{m}\ 32^{s}.9$, 28° 17′ 2″	17235	7¾	12 26 33.7	28 16 41
5235	12 27 6.3	178 23 29	1	Both moments appear to be recorded about 13^{m} too late. The observations of polar stars 1752 Jan. 29 seem untrustworthy in general.	17241	7½	12 23 40	88 25
A 5295	12 37 4.7	119 12 28	123	Can only be reconciled by diminishing both moments by 5^{s}. See Argelander's remarks, Bonn Obs. VII, 241.	17468	7¼	12 37 0.0	29 12 37
A 5329	12 42 29.6	120 8 9	123	Assume egress at 12 46 5 instead of 12 46 0, which gives the position $12^{h}\ 42^{m}\ 32^{s}.1$, 30° 7′ 4″	17583	7	12 42 31.5	30 7 16
5333	12 43 17.1	136 5 30	79	Interchanging the times of egress, we find the positions $12^{h}\ 42^{m}\ 37^{s}.0$, 46° 19′ 24″ 12 44 5 .6, 45 42 38	17595	7	12 42 35.4	46 19 34
5334	12 43 27.7	135 29 23			17635	7	12 44 5.7	45 42 24
A 5365	12 48 20.0	119 26 39	123	Assume ingress at 12 46 47 instead of 12 46 57, which gives the position $12^{h}\ 48^{m}\ 15^{s}.5$, 29° 28′ 48″.	17725	7½	12 48 14.1	29 28 48
5439	12 59 12.2	131 9 47	97	Assume egress at 13 1 38 instead of 13 2 38, which gives the position $12^{h}\ 58^{m}\ 41^{s}.0$, 41° 21′ 12″	17958	6¾	12 58 37.9	41 21 51
5477	13 4 2.7	167 37 35	13	Assume both moments 10^{s} earlier than recorded, which gives the position $13^{h}\ 3^{m}\ 52^{s}.6$, 77° 38′ 38″ — being that of no. 5473, observed also on p. 17 as $13^{h}\ 3^{m}\ 54^{s}.9$, 77° 39′ 16″	18163	8½	13 3 53.5	77 37 47
5481	13 5 5.0	159 19 23	33	Assume ingress at 13 3 23 instead of 13 4 23, which gives the position $13^{h}\ 4^{m}\ 35^{s}.7$, 69° 14′ 2″	18141	7¾	13 4 32.1	69 13 28
5537	13 12 19.8	138 3 6	72	Assume ingress at 13 16 8 instead of 13 15 58, which gives the position $13^{h}\ 12^{m}\ 24^{s}.7$, 48° 4′ 44″	18294	6¾	13 12 22.6	48 4 19
5599	13 22 21.7	130 54 28	97	The recorded egresses of these stars are to be interchanged, that given for no. 5602 increased by 5^{s}. The ingress of no. 5602 is assumed as 13 22 20 instead of 13 22 30. These changes give the positions $13^{h}\ 21^{m}\ 44^{s}.8$, 41° 7′ 44″ 13 23 9 .8, 41 13 39	18496	7¼	13 21 44.9	41 7 37
5602	13 22 36.2	131 29 36			18527	8	13 23 9.2	41 13 44
5601	13 22 20.0	131 31 29	97	Assume ingress as recorded 10^{s} too late, like that of no. 5602, which was but 1^{s} later. This gives the position $13^{h}\ 22^{m}\ 25^{s}.2$, 41° 29′ 37″	18506	7	13 22 25.4	41 29 37
5672	13 31 54.0	171 41 2	9	Assume egress at 13 41 11 instead of 13 41 21, which gives the position $13^{h}\ 31^{m}\ 49^{s}.7$, 81° 40′ 25″	18868	7¾	13 31 49.1	81 40 36
5694	13 35 54.9	167 21 50	17	Assume ingress at 13 37 46 instead of 13 37 51, which gives the position $13^{h}\ 35^{m}\ 53^{s}.1$, 77° 21′ 17″	18896	6½	13 35 53.2	77 20 55
A 5701	13 36 17.0	118 44 48	123	Assume ingress at 13 37 4 instead of 13 36 29, which gives the position $13^{h}\ 36^{m}\ 34^{s}.9$, 28° 37′ 10″	18801	8	13 36 34.1	28 37 19
A 5703	13 36 30.2	119 55 5	122	Assume egress at 13 40 20 instead of 13 40 30, which gives the position $13^{h}\ 36^{m}\ 25^{s}.1$, 29° 57′ 17″	18799	7	13 36 26.3	29 57 7
A 5709	13 37 37.1	120 6 43	122	I find no plausible mode of reconciling these observations except by arbitrary change of both moments. Assuming ingress 15^{s}, and egress 5^{s}, earlier than recorded, we should find the position $13^{h}\ 37^{m}\ 27^{s}.2$, 30° 4′ 31″. There can be little doubt as to the star which has no large proper motion. See Argelander, Bonn Obs. VII, 128.	18832	7½	13 37 26.4	30 4 1
5731	13 39 44.2	143 11 41	63	Am unable to reconcile these observations with any existing star. The egress of no. 5705 was noted at the instant given for the ingress of this.				
5741	13 40 9.3	142 53 36	63	Another observation of no. 5738, observed 1752, Feb. 11. Both moments appear to be nearly 3^{s} too late.	18904	6½	13 40 7.0	52 53 29
5751	13 41 1.7	120 54 1	122	Assume ingress at 13 41 54 instead of 13 42 4, which gives the position $13^{h}\ 40^{m}\ 56^{s}.9$, 30° 51′ 51″	18902	7½	13 40 55.7	30 51 30
5752	13 41 25.4	135 31 34	79	Assume egress at 13 44 20 instead of 13 45 20, which gives the position $13^{h}\ 40^{m}\ 56^{s}.3$, 45° 21′ 14″	18919	6½	13 40 55.9	45 21 2
5756	13 41 54.0	135 18 59	79	Assume egress at 13 44 11 instead of 13 45 11, which gives the position $13^{h}\ 41^{m}\ 24^{s}.7$, 45° 8′ 33″	18929	7	13 41 22.9	45 8 52
5762	13 42 23.6	151 25 52	45	Wrongly reduced in British edition. The place should be given as $13^{h}\ 42^{m}\ 23^{s}.6$, 61° 32′ 48″	18971	7½	13 42 22.7	61 33 0

Catalogue-position.			C. A.		Arg. Gen. Catal. for Equinox 1750.0			
No.	R.A.	N.P.D.			No.	Mag	α	δ
	h m s	° ′ ″	page				h m s	° ′ ″
5767	13 43 7.7	123 28 11	115	Assume egress at 13 44 4 instead of 13 45 4, which gives the position $13^h 42^m 36^s.9$, 33° 40′ 12″	18943	7½	13 42 35.6	33 40 3
5806	13 50 33.2	153 54 33	39	Wrongly reduced in British edition. The place should be given as $13^h 55^m 21^s.9$, 61° 57′ 30″	19239	7¾	13 55 25.7	61 57 47
5846	13 57 13.7	155 23 55	39	Wrongly reduced in British edition. The place should be given as $13^h 57^m 17^s.4$, 65° 23′ 55″	19280	6¼	13 57 16.4	65 24 10
5887	14 4 27.4	131 56 21	97	Assume egress at 14 6 10 instead of 14 5 55, which gives the position $14^h 4^m 35^s.2$, 41° 53′ 34″	19371	6½	14 4 35.0	41 53 33
M 5900	14 6 24.1	155 37 52	39	Interchanging times of egress of these two stars, we have the positions $14^h 7^m 22^s.8$, 65° 25′ 31″ 14 10 44.7, 66 31 33	19491	7	14 7 20.7	65 25 1
M 5942	14 11 43.5	156 23 9			19578	6¼	14 10 50.1	66 34 39
A 5926	14 9 58.7	118 30 28	128	Assume ingress at 14 10 53 instead of 14 10 43, which gives the position $14^h 10^m 3^s.8$, 28° 28′ 17″	19499	8¼	14 10 4.2	28 28 6
M 5974	14 16 58.4	145 26 56	63	Wrongly reduced in British edition. The place should be given as $14^h 17^m 28^s.2$, 55° 26′ 57″	19709	7	14 17 25.8	55 26 37
5989	14 19 21.3	128 26 30	103	I cannot explain this observation without assuming errors everywhere. Yet if we could suppose it made in the lower part, with ingress at 14 16 8 instead of 14 16 3, and egress at 14 21 5 instead of 14 20 10, we should obtain the position $14^h 19^m 52^s.7$, 37° 23′ 22″, or Z.C. XIV, 1771.	Z.C.1771	8	14 19 53.1	37 23 27
M 6006	14 21 28.0	173 44 57	9	Interchanging times of egress, we have the positions of π_1 and π_2 *Octantis* $14^h 20^m 58^s.8$, 82° 9′ 5″ 14 21 13.4, 81 58 40	20034	6	14 20 56	82 9 51
M 6009	14 21 54.2	172 18 56	9		20104	6	14 24 10	81 59 7
6043	14 26 0.5	131 46 20	97	Assume egress at 14 28 16 instead of 14 27 54, which gives the position $14^h 26^m 11^s.9$, 41° 42′ 12″	19889	7½	14 26 12.1	41 41 56
6059	14 27 51.3	155 30 52	39	Wrongly reduced in British edition. The place should be given as $14^h 27^m 56^s.2$, 65° 30′ 53″	19980	6	14 27 57.2	65 31 10
6078	14 30 26.7	148 18 42	57	These are two observations of the same star. Assume on p. 57, 14 30 14 instead of 14 30 4, and on p. 51, 14 29 41 instead of 14 29 36. These give the positions $14^h 30^m 31^s.3$, 58° 20′ 1″ 14 30 31.5, 58 20 36	20022	7	14 30 31.8	58 20 22
6079	14 30 28.9	148 21 15	51					
6112	14 35 8.6	121 11 14	115	Assume egress at 14 37 55 instead of 14 36 55, which gives the position $14^h 35^m 37^s.9$, 31° 23′ 59″	20102	7½	14 35 34.8	31 24 24
6150	14 40 57.1	161 9 40	27	Assume egress at 14 46 46 instead of 14 46 56, which gives the position $14^h 40^m 52^s.0$, 71° 10′ 32″	20331	7½	14 40 51.9	71 10 26
6167	14 42 58.8	160 53 7	27	Assume egress at 14 50 19 instead of 14 50 29, which gives the position $14^h 42^m 53^s.6$, 70° 51′ 0″	20379	6¾	14 42 53.1	70 53 53
A 6210	14 49 11.5	116 50 49	129	Reducing for the lower part, we have the position $14^h 49^m 12^s.5$, 27° 3′ 59″	20426	7¼	14 49 12.2	27 3 44
M 6211	14 54 27.4	115 37 19	135	Assume ingress at 14 51 12 instead of 14 54 42, which gives the position $14^h 54^m 12^s.7$, 25° 30′ 32″	20537	7¼	14 54 13.1	25 31 10
M 6250	14 55 20.2	112 45 10	135	Wrongly reduced in British edition. The place should be given as $14^h 55^m 20^s.2$, 23° 1′ 9″	20557	6¼	14 55 19.5	23 0 42
6283	14 59 50.8	131 55 39	99	Assume ingress at 14 56 31 instead of 14 59 31, which gives the position $14^h 58^m 25^s.7$, 41° 21′ 48″	20611	8	14 58 24.1	41 21 48
6321	15 4 47.7	155 6 52	39	Assume egress at 15 11 46 instead of 15 10 46, which gives the position $15^h 5^m 15^s.3$, 65° 12′ 46″	20840	7	15 5 20.1	65 12 30
6361	15 9 37.3	125 19 23	111	The egresses for nos. 6361, 6372 and 6374, are confused in the record. Assume here 15 12 13, as given for no. 6374, and we have the position $15^h 9^m 39^s.9$, 35° 18′ 20″	20869	7¼	15 9 39.7	35 17 31
6371	15 10 6.2	156 33 23	39	Assuming egress at 15 11 52 instead of 15 10 47, we have the position $15^h 10^m 40^s.1$, 66° 26′ 50″	20973	7¾	15 10 11.2	66 27 10
6372	15 10 12.8	125 36 57	111	Assume egress at 15 12 8 as given for no. 6361, and ingress at 15 7 33 instead of 15 7 43. The resulting position is then $15^h 10^m 11^s.0$, 35° 33′ 39″	20882	8	15 10 11.0	35 34 9
6374	15 10 43.3	125 45 11	111	Assume egress at 15 12 2, as given for no. 6372, and we have the position $15^h 10^m 24^s.1$, 35° 41′ 17″	20892	7	15 10 23.6	35 41 38
6376	15 11 25.0	125 51 21	111	Assume egress at 15 12 35 instead of 15 12 30, which gives the position $15^h 11^m 22^s.4$, 35° 52′ 22″	20909	6	15 11 22.8	35 52 7

Catalogue-position.			C.A.		Arg. Gen. Catal. for Equinox 1750.0			
No.	R.A.	N.P.D.			No.	Mag	α	δ
	h m s	° ′ ″	page				h m s	° ′ ″
M 6425	15 19 7.2	114 19 19	135	Reducing for upper part of reticule, we find the position $15^h\ 19^m\ 6^s.1$, 24° 14′ 41″	21077	7½	15 19 7.0	21 14 43
6452	15 22 49.1	131 57 42	99	Assume ingress at 15 22 21 instead of 15 22 11, which gives the position $15^h\ 22^m\ 55^s.6$, 41° 55′ 44″. Another observation of no. 6453.	21195	7½	15 22 55.0	41 55 33
A 6454	15 23 2.7	117 18 59	128	Assume ingress at 15 21 0 instead of 15 20 50, which gives the position $15^h\ 23^m\ 7^s.6$, 27° 21′ 14″	21180	6½	15 23 7.5	27 21 42
6460	15 23 43.2	179 30 45	1	Star was *B Octantis*, and the instrument was evidently much out of the meridian.	29042	6½	15 37 3	89 30 10
6467	15 24 23.6	124 22 34	111	Assume egress at 15 26 45 instead of 15 25 45, which gives the position $15^h\ 24^m\ 52^s.9$, 34° 34′ 45″	21231	7¼	15 24 52.6	34 35 27
A 6485	15 26 13.3	118 26 39	125	Assume egress at 15 26 51 instead of 15 26 46, which gives the position $15^h\ 26^m\ 15^s.8$, 28° 27′ 46″	21249	7½	15 26 16.6	28 28 13
A 6502	15 29 7.1	119 46 1	125	Assume ingress at 15 26 46 instead of 15 26 16, which gives the position $15^h\ 29^m\ 21^s.9$, 29° 52′ 38″	21326	7½	15 29 20.4	29 52 19
6505	15 30 12.1	126 19 54	111	Assume egress at 15 31 19 instead of 15 30 19, which gives the position $15^h\ 30^m\ 42^s.8$, 36° 7′ 44″	21359	7¾	15 30 41.7	36 7 52
6593	15 41 4.0	151 47 21	41	Assuming egress at 15 44 36 instead of 15 44 26, which gives the position $15^h\ 41^m\ 9^s.0$, 61° 48′ 28″. Another observation of no. 6595.	21659	6¾	15 41 8.0	61 48 9
6661	15 48 38.5	142 13 8	69	Assume ingress at 15 47 3 instead of 15 46 3, which gives the position $15^h\ 49^m\ 6^s.5$, 52° 22′ 29″	21813	7¼	15 49 3.8	52 22 30
6676	15 50 3.7	145 22 34	63	Wrongly reduced in British edition. The place should be given as $15^h\ 50^m\ 54^s.7$, 55° 22′ 35″	21867	7½	15 50 53.6	55 22 45
M 6740	15 58 9.6	118 17 17	125	Wrongly reduced in British edition. The place should be given as $15^h\ 58^m\ 10^s.1$, 28° 23′ 17″	21970	7½	15 58 9.9	28 23 27
M 6741	15 58 13.8	119 22 30	125	Typographical error in British edition. The place should be given as $15^h\ 58^m\ 13^s.8$, 29° 32′ 29″	21973	7¾	15 58 14.2	29 32 48
6742	15 58 19.2	147 17 37	5	Assuming both of Lacaille's moments as 1^m too late, we have the position $15^h\ 57^m\ 19^s.2$, 57° 17′ 37″	22009	7¾	15 57 20.3	57 16 57

OCCULTATION OF *JUPITER*, OBSERVED 1889 SEPT. 3,

AT THE LEANDER MCCORMICK OBSERVATORY OF THE UNIVERSITY OF VIRGINIA,

BY ORMOND STONE.

		Local Sid. Time h m s
1.	Satellite III, disappearance,	20 18 14.5
2.	" II, "	20 22 54.3
3.	*Jupiter*, 1st contact,	20 28 41.1
4.	" 2d "	20 30 49.0
5.	Satellite I, disappearance,	20 31 19.3
6.	" III, reappearance,	21 13 3.4
7.	Satellite IV, reappearance,	21 17 6.9
8.	*Jupiter*, 3d contact,	21 18 31.2
9.	" 4th "	21 20 23.2
10.	Satellite I, reappearance,	21 20 50.4

Phenomena 6, 7, 8 and 9 a little late. Instrument: 26-in. refractor, magnifying power 175.

COMET *d* 1889 (*BROOKS, July 6*),

BY E. E. BARNARD.

The excessively cloudy weather that has marked the winter throughout at Mt. Hamilton, has prevented my obtaining many observations of this comet. Since its important nature was made known by Mr. Chandler, I have observed it on every occasion that it could be seen.

In the last few observations the comet has been extremely difficult because of its faintness, and the presence about it of the zodiacal light.

In the March observations nothing was visible of the comet except the slight central condensation that had previously marked the brightest part: this was scarcely over 5″ or 6″ in diameter. The comet looked like a very small indefinite nebula, and though difficult to see, it could be bisected with great exactness on account of its small size.

From the time of the discovery, on August 1, of the companions that attended this comet, until their disappearance, they were observed every night that they could be seen with the great telescope. The nearer companion *B* was observed for distance and position-angle on twenty-three nights, and the distant companion *C*, on fifty-nine nights. The first of these companions was last seen on September 5, while the distant one was observed last on November 25, when it was at the limit of visibility in the great telescope. It had then approached the main comet to within 250″, or a less distance than when discovered, the maximum distance (357″) being attained about the twentieth of September. The observed change of distance was mainly due to perspective. From the 3d of August to Nov. 25 the position-angle of this companion did not change more than 2°.

The observation of November 11 was obtained by a carefully noted central occultation of a 13$^{\text{M}}$ star by the comet's nucleus while measuring the companion *C* with the great telescope. The cloudy weather prevented any observation for the position of the small star, though it was carefully located, and will be observed with the 12-inch as soon as it is visible in the morning sky. In reference to this occultation, I feel positive that the nucleus blotted out the star. For a few seconds, there was a diminution of the light at the point of nucleus and star: the light then reappeared, and the star and the nucleus were seen separate shortly after. I was certain of the diminution of the light, but whether due to the interference of the nucleus or to the rather poor seeing, it was not possible to tell.

Mt. Hamilton, 1890 *April* 3.

FILAR-MICROMETER OBSERVATIONS OF COMET *d* 1889 *BROOKS, July 6.*

MADE WITH THE 12-INCH EQUATORIAL OF THE LICK OBSERVATORY,

BY E. E. BARNARD.

1889 Mt. Hamilton M.T.		✳	No. Comp.	☄—✳		☄'s apparent		log $p\Delta$	
				Δα	Δδ	α	δ	for α	for δ
d	h m s			m s	′ ″	h m s	° ′ ″		
July 8	14 50 23	1	8 , 6	+3 21.48	—10 18.9	23 46 26.03	— 8 55 57.1	n9.321	0.797
9	13 58 13	1	14 , 6	+4 20.13	— 4 31.9	23 17 24.72	— 8 50 9.9	n9.474	0.758
10	14 37 54	1	8 , 6	+5 21.45	+ 1 29.6	23 48 26.06	— 8 44 8.2	n9.342	0.792
23	13 46 29	2	10 , 6	+0 32.62	— 1 22.6	23 59 23.23	— 7 36 6.3	n9.389	0.783
Aug. 1	13 14 2	3	12 , 6	—0 47.37	+ 4 7.2	0 4 25.2	— 7 48.8	n9.582	0.782
6	12 46 19	4	12 , 6	+1 45.09	— 3 7.8	0 6 31.05	— 6 38 21.1	n9.422	0.777
18	11 58 8	5	3		+ 0 59.1		— 6 11 51.2		0.776
	12 17 21	5	12	—2 1.59		0 8 11.61		n9.373	
21	11 38 31	5	10 , 6	—2 16.61	+ 6 34.5	0 7 56.66	— 6 6 15.4	n9.455	0.772
25	12 59 10	6	3		— 6 1.6		— 5 57 42.2		0.775
	13 20 45	6	8	+2 30.61		0 7 10.60		n8.663	
29	11 43 2	6	12 , 6	+1 20.42	— 2 36.8	0 6 0.46	— 5 54 17.4	n9.322	0.776
31	12 16 24	6	14 , 6	+0 35.06	— 0 0.2	0 5 15.12	— 5 51 40.5	n9.114	0.777
Sept. 2	10 21 32	6	16 , 6	—0 13.30	+ 2 19.0	0 4 26.80	— 5 49 21.0	n9.505	0.765
Oct. 10	9 41 41	7	12 , 6	+1 9.72	+ 0 41.1	23 42 53.5	— 4 30.2	n8.924	0.769
11	7 55 53	7	12 , 6	+0 49.56	+ 4 30.2	23 42 33.4	— 4 26.4	n9.439	0.763
28	11 48 46	8	12 , 6	—1 37.05	+ 0 26.4	23 40 35.2	— 2 49.1	9.476	0.750
	11 48 46	9	12	—1 15.99		23 40 35.3		9.476	
Nov. 9	10 35 2	10	10 , 6	+2 26.78	— 5 11.8	23 44 30.12	— 1 27 37.6	9.400	0.739
	10 35 2	11	10	+1 56.67		23 44 30.06		9.400	
10	8 33 43	10	10 , 6	+2 55.05	+ 2 8.8	23 44 58.38	— 1 20 17.0	8.342	0.741
	8 33 43	11	10	+2 25.03		23 44 58.41		8.342	
11	7 20 42	12		0.00	0 0.0			n9.089	0.739
15	10 12 15	13	10 , 6	—1 8.48	— 7 50.2	23 47 59.55	— 0 38 3.8	9.393	0.732
21	7 50 44	14	8 , 3	+1 38.89	+ 0 4.8	23 52 19.1	+ 0 13.9	8.462	0.725
24	10 20 54	15	12 , 4	+0 33.07	+ 0 5.3	23 54 59.7	+ 0 13.0	9.507	0.717
Dec. 12	9 34 1	16	3		— 6 21.5		+ 3 21 51.7		0.698
15	8 16 4	17	18 , 8	—0 15.21	+ 1 0.8	0 18 2.66	+ 1 15 9.1	9.288	0.697
1890 Jan. 8	8 36 26	18	12 , 6	+1 13.14	+ 3 22.0	0 52 31.61	+ 8 11 18.5	9.521	0.656
10	10 0 19	19	16 , 6	—0 10.98	— 4 32.2	0 55 46.38	+ 9 1 27.8	9.610	0.666
21	8 4 58	20	7 , 7	—0 46.98	— 4 32.7	1 13 37.66	+11 7 38.3	9.720	0.629
Feb. 7	8 25 14	21	2	+0 34.19		1 43 3.6		9.610	
7	8 19 9	21	3		— 4 23.1		+11 14.5		0.626
9	7 51 52	22	5		— 3 46.8		+11 26 14.5		0.621
9	8 12 14	22	42	—0 0.71		1 46 37.27		9.183	
Mar. 12	8 43 48	23	8 , 6	—2 19.68	+ 3 18.7	2 41 11.82	+19 13 35.7	9.691	0.672
13	8 18 39	24	10 , 5	—2 29.09	— 3 4.6	2 46 4.49	+19 52 26.6	9.681	0.618
14	8 4 51	24	16 , 7	—0 35.23	+ 5 10.3	2 47 58.34	+20 1 11.4	9.677	0.629
20	8 24 13	25	8 , 6	+1 36.99	— 9 37.9	2 59 32.13	+20 52 50.7	9.691	0.660

Mean Places for 1889 and 1890 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	23 43 3.51	+1.04 +1.11	— 8 45 47.5	+ 9.3 + 9.7	W.B., XXIII 847
2	23 58 49.21	+1.40	— 7 34 55.1	+11.4	W.B., XXIII 1170
3	0 5 11.0	+1.60	— 7 53.1	+12.5	SDM., —8° 10
4	0 4 44.23	+1.73	— 6 35 26.0	+12.7	Schjellerup 29
5	0 10 11.24	+1.96 +2.03	— 6 13 4.5	+14.2 +14.6	½(Paris 203+Σ15)
6	0 1 37.87	+2.12 +2.23	— 5 51 55.4	+14.8 +15.4	½(Paris 83+Schj. 27)
7	23 41 41.4	+2.42 +2.43	— 4 31.1	+15.5 +15.1	SDM., —4° 5955
8	23 42 9.8	+2.36	— 2 49.7	+15.1	SDM., —3° 5706
9	23 41 19.9	+2.36	— 2 50.6	+15.1	SDM., —3° 5704
10	23 42 0.89	+2.45	— 1 22 40.7	+14.9	⅓(2 Yar. 10778+W.B., XXIII 817)
11	23 42 30.94	+2.44	— 1 23 28.4	+14.9	W.B., XXIII 830, comp. with No. 10*
12					Star 13ᴹ
13	23 49 5.78	+2.12	— 0 30 28.5	+14.9	Yarnall 10846
14	23 50 38.0	+2.17	+ 0 13.6	+14.5	DM., +0° 5070
15	23 54 24.4	+2.18	+ 0 42.7	+14.7	DM., +0° 5078
16	0 10 15		+ 3 38 4.7	+14.5	Schjellerup 69
17	0 18 15.77	+2.10	+ 4 13 53.8	+14.5	Comp. with W.B., 0ʰ 217†
18	0 50 49.51	—1.04	+ 8 38 2.1	— 5.6	W.B., O 851
19	0 55 58.11	—1.08	+ 9 9 5.6	— 5.6	W.B., O 944
20	1 14 25.71	—1.07	+11 12 16.4	— 5.4	B.B., +11° 169
21	1 42 30.6	—1.17	+14 19.0	— 5.2	DM., +11° 281
22	1 46 39.20	—1.19	+14 40 6.0	— 4.7	B.B., +14° 294
23	2 46 32.84	—1.34	+19 40 21.8	— 4.8	B.B., II 1075
24	2 48 34.92	—1.34 —1.35	+19 55 35.9	— 4.7 — 4.8	W.B., II 1122
25	2 57 56.54	—1.40	+21 2 32.5	— 3.9	W.B., II 1343

* Star 11 — Star 10., $\Delta\alpha = +0^m\ 30^s.05$ (10), $\Delta\delta = -0'\ 47''.7$ (3)

† Star 17 — W.B., O 217, $\Delta\alpha = +3^m\ 32^s.60$ (4); $\Delta\delta = +4'\ 6''.0$ (2).

A 9ᴹ.2 star was observed at the same time; following is its position:

Star 9ᴹ.2 — W.B., O 217, $\Delta\alpha = +2^m\ 27^s.50$ (4); $\Delta\delta = \pm 0'\ 0''.0$, same parallel.

Hence, star 9ᴹ.2 (1889.0) $\alpha = 0^h\ 17^m\ 10^s.67$, $\delta = +4^\circ\ 9'\ 47''.8$ = DM., 3° 36 (9ᴹ.5)

The observations of this comet were all made in the manner described in the observations of Faye's comet (*A.J.* 196). One revolution of the micrometer-screw = 14″.057 ±0″.004. The observation of July 23 was made with the same micrometer, in the 6½-inch equatorial, during the temporary derangement of the 12-inch. On this instrument the value of the screw was = 34″.20. On Dec. 12, the sky clouded before the observations could be completed.

OBSERVED MAXIMA AND MINIMA OF VARIABLE STARS.

By PAUL S. YENDELL.

R Lyrae.

A series of 92 observations of this star, from 1889 April 22 to Dec. 23, shows three maxima, and as many minima, as follows:

Maxima	M	Minima	M
1890 June 10	4.2	1890 May 21	5.5
Oct. 27	4.25	July 8	5.2
Dec. 10	4.2	Nov. 25	5.2

The magnitudes given above indicate a considerably greater light-range than is usually attributed to this star; they are careful estimates from the DM. magnitudes of the comparison-stars; the strong red color of *R*, however, renders all such estimates open to question.

Dorchester. 1890 *April* 23.

U Orionis.

From 1889 Nov. 14 to 1890 Jan. 28, 35 observations of this star were secured; when first seen it was fainter than the tenth magnitude, and from this time until Dec. 7 its increase was slow; after this date it rose more rapidly, attaining a maximum of 6ᴹ.4 in 1890 Jan. 3; its decline from this date was about as rapid as its increase, but interrupted by a secondary maximum of 6ᴹ.7 about Jan. 20, according to my observations.

R Leonis.

R Leonis has been observed 21 times from 1890 Jan. 13 to April 11. A maximum is indicated on Feb. 20, when the star's light was 4.5 steps > 18 *Leonis*, or 5ᴹ.8.

ELEMENTS OF COMET 1890 I (*BORRELLY*),

BY ENSIGN H. S. CHASE, U.S. NAVY.

[Communicated by the Superintendent.]

The following elements of this comet have been computed from the two Marseilles observations of Dec. 12, 1889; the Munich observations of Dec. 21, and the Ann Arbor observations of Jan. 3, 1890.

$$T = 1890 \text{ Jan. } 26.260373 \text{ Wash. M.T.}$$

$$\left.\begin{aligned} \pi &= 208^\circ\ 15'\ \ 6''.8 \\ \Omega &= \ \ \ 8\ \ 17\ \ 11\ .2 \\ i &= \ 56\ \ 42\ \ 25\ .4 \end{aligned}\right\} 1890.0$$

$$\log q = 9.430882$$

Naval Observatory, 1890 *April* 9.

The middle place is represented as follows:

$$\cos\beta\,\Delta\lambda = +1''.4, \qquad \Delta\beta = -1''.4$$

The values of the equatorial rectangular coordinates for the mean equinox 1890.0 are

$$\begin{aligned} x &= [9.996828]\ r\sin(294^\circ\ 32'\ 10''.7 + v) \\ y &= [9.326191]\ r\sin(238\ \ 33\ \ 51\ .4 + v) \\ z &= [9.993294]\ r\sin(203\ \ 18\ \ 18\ .1 + v) \end{aligned}$$

SUN-SPOT OBSERVATIONS, NOVEMBER 1889 TO APRIL 1890.

BY PAUL S. YENDELL.

The observations here given are in continuation of the series heretofore published in Vols. VIII and IX of this Journal. They have been much interrupted by unfavorable weather and illness. The conditions of observation remain unchanged.

Date	C.M.T.	Gps.	Sps.
1889 Nov. 1	22 15	0	0
3	20 15	0	0
5	20 30	0	0
7	23 15	0	0
10	20 45	0	0
11	21 0	0	0
13	20 45	0	0
14	21 45	0	0
15	20 45	0	0
20	20 45	0	0
1889 Nov. 25	20 15	0	0
Dec. 1	21 15	0	0
4	20 45	0	0
12	20 15	0	0
15	21 15	0	0
20	21 0	0	0
1890 Jan. 13	21 0	0	0
21	21 0	0	0
1890 Jan. 22	22 0	0	0
23	21 15	0	0
24	20 30	0	0
27	21 15	0	0
Feb. 3	21 15	0	0
9	22 45	0	0
13	22 15	0	0
18	21 15	0	0
20	20 30	0	0
1890 Mar. 3	20 40	0	0
6	20 30	0	0
9	20 35	1	5
12	21 15	0	0
16	20 25	0	0
17	20 25	0	0
19	20 25	0	0
23	20 25	0	0
26	20 15	0	0
30	20 35	0	0

NOTES.

1889 Nov. 3. Seeing very good. — Nov. 5. Seeing bad. — Nov. 16 and 20. Seeing bad. — Dec. 4 Seeing poor; thin cloud. — Dec. 12. Seeing very poor. — Dec. 15. Seeing very bad; in lee of chimney. — Dec. 20. Seeing good. — 1890 Jan. 13. Seeing poor. — Jan. 21 and 23. Very bad. — Jan. 24 and 25. Fair. — Jan. 27. Very bad; cold. Feb. 10 and 14. Seeing poor. — March 3. Very bad; hazy. — March 6. Very bad; temperature outside +6°. — March 23. Very bad, observation nearly worthless. — March 26 and 30. Good

Boston, 1890 *April* 22.

FILAR-MICROMETER OBSERVATIONS OF COMET *f* 1889 (*SWIFT, Nov. 16*),

MADE WITH THE 12-INCH EQUATORIAL OF THE LICK OBSERVATORY.

BY E. E. BARNARD.

1890 Mt. Hamilton M.T.	*	No. Comp.	☄ — * Δα	☄ — * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
			m s	′ ″	h m s	° ′ ″		
Jan. 10 8 43 30	8	12 , 8	+0 21.66	+1 58.1	1 27 29.63	+26 16 16.7	9.528	0.380
21 9 45 41	9	8 , 8	—0 52.61	—6 11.7	2 7 20.80	+28 4 11.8	9.615	0.153

Mean Places for 1890.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
8	1 27 8.89	—0.92	+26 11 6.6	+12.0	Weisse's Bessel I. 551
9	2 8 14.48	—1.04	+28 10 19.5	+10.0	" " II. 138

January 21. The declination is better than the right-ascension. Observations interrupted. The comet very faint.

These two observations were the only ones permitted by the continuous cloudy weather, except those published in *A. J.* 207-209.

ELEMENTS AND EPHEMERIS OF COMET *a* 1890,

By GEORGE A. HILL.

From an observation by Mr. Wendell on March 21, and two by Prof. Frisby, on March 26, and April 1, I have computed the following set of elements, and an ephemeris for Comet *a* 1890 (Brooks).

$$T = 1890 \text{ June } 1.8414 \text{ G.M.T.}$$

$$\left.\begin{aligned} ☊ &= 320^\circ\ 26'\ 8 \\ \omega &= 69\ \ 18\ \ 11 \\ i &= 120\ \ 43\ \ 39 \end{aligned}\right\} 1890.0$$

$$\log q = 0.278946$$

$$\Delta\lambda \cos\beta = -2''.5, \qquad \Delta\beta = -3.2$$

Ephemeris for Greenwich Midnight.

Date	App. α	App. δ	log *r*	log Δ	Br.
	h m s	° ′			
1890 May 1	20 58 12	+29 58	0.2879	0.2777	2.46
2	57 30	30 50			
3	56 17	31 42			
4	55 0	32 34			
5	53 43	33 26	0.2858	0.2593	2.71
6	52 30	34 19			
7	51 16	35 13			
8	49 47	36 5			
9	48 10	36 58	0.2840	0.2454	2.91
10	46 24	37 53			
11	44 27	38 49			
12	20 42 21	+39 44			
1890 May 13	20 40 4	+40 41	0.2821	0.2285	3.17
14	37 37	41 39			
15	35 1	42 37			
16	32 15	43 35			
17	29 22	44 33	0.2817	0.2195	3.31
18	26 29	45 31			
19	23 20	46 30			
20	19 56	47 30			
21	16 18	48 29	0.2801	0.2085	3.51
22	12 30	49 27			
23	8 23	50 26			
24	20 3 57	51 24			
25	19 59 16	52 22	0.2793	0.2003	3.66
26	54 25	53 19			
27	49 10	54 15			
28	43 32	55 9			
29	37 27	55 59	0.2790	0.1950	3.76
30	31 1	56 38			
May 31	24 10	57 9			
June 1	16 56	57 42			
2	19 9 17	+58 11	0.2789	0.1971	3.72

The unit of brightness is taken from the date of discovery of the comet.

Washington, D.C.

NEW ASTEROIDS.

A small planet of the 13th magnitude was discovered by Palisa at Vienna, in the position

1890 April 25.4568 G.M.T. $\alpha = 14^h\ 21^m\ 7^s.7$, $\delta = -11^\circ\ 6'\ 29''$.

Daily motion, —15′ in α. and 5′ northward.

A second, of the 12th magnitude, was found by Palisa on the same night, in the position

1890 April 25.4643 G.M.T. $\alpha = 14^h\ 19^m\ 37^s.0$, $\delta = -10^\circ\ 40'\ 1''$.

Daily motion, —17′ in α, and 1′ southward.

The latter is supposed to be no. 155, *Scylla*.

CORRIGENDUM.

No. 215, p 180, col. 2, line 5, for $0''.011\tau$ put $0''.012\tau$, and inclose the whole formula, after the negative sign, in brackets.

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Elements and Ephemeris of Comet *a* 1890, by Mr. George A. Hill.
New Asteroids.
Corrigendum.

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ON A METHOD OF CORRECTING A FIRST PARABOLIC ORBIT TO REPRESENT A LATER OBSERVATION.

By Rev. GEO. M. SEARLE.

In no. 206 of the *Astronomical Journal*, a method was given of computing a first approximate parabolic orbit, which has the advantage of dispensing with the separate calculation of the two radii-vectores for the extreme places, and of making the formula for the time-equation more simple. As some inaccuracy may however be introduced (considering the very short intervals here concerned) by the calculation of some small quantities by the difference of larger ones, the following set of formulas will probably be more reliable.

In the first place, a and b are computed from the observed places by the expressions

$$a = \sin(\lambda''-L') - m'\tan\beta''$$
$$b = m'\tan\beta - \sin(\lambda-L')$$

in which $m' = \sin(\lambda'-L')\cot\beta'$

In these, we have omitted R', as all we need is the quotient $\frac{b}{a}$.

We have, then, as usual, for the ratio of the curtate distances,

$$M = \frac{t''-t'}{t'-t}\cdot\frac{b}{a}$$

We now compute

$$e = \cos(\lambda''-\lambda) + \tan\beta\tan\beta''$$
$$\varepsilon = \frac{R\cos(\lambda''-L)}{e}$$
$$\varepsilon' = \frac{RR''\cos(L''-L)}{e}$$
$$\varepsilon'' = \frac{R''\cos(\lambda-L'')}{e}$$

$$g\sin(G-L) = R''\sin(L''-L)$$
$$g\cos(G-L) = R''\cos(L''-L) - R\ ,$$
$$g' = 4g\sin(\lambda_1-G)\sin\tfrac{1}{2}(\lambda''-\lambda)$$
$$g'' = g\cos(\lambda''-G)$$

in which $\lambda_1 = \frac{1}{2}(\lambda''+\lambda)$

Then $i_0 = 4\sin^2\frac{1}{2}(\lambda''-\lambda) + \sec^2\beta\sec^2\beta''\sin^2(\beta''-\beta)$
$\theta' = k(t''-t)$

With our value of M, let $\mu = 2(1-M)$. For the short intervals concerned, μ will almost always be a small quantity, and usually positive.

Compute now $e_0 = e - \frac{1+M}{2}\sec^2\beta''$

$$\rho_0 = \frac{\varepsilon+\varepsilon''}{2} + \frac{\varepsilon''}{4}\cdot\frac{\mu}{M}$$
$$n = \frac{\varepsilon'}{M} - \rho_0^2$$
$$i = i_0 + \mu e$$
$$d = \frac{g'+\mu g''}{i}$$

These quantities are obtained very expeditiously, on account of the small value of μ.

Our trial equation is now $\kappa^2 r_1 = 2\theta'^2$
in which $\kappa^2 = g^2 + i\rho(\rho+d)$
and r_1 is got by

$$\tan Y = \frac{\sqrt{n}}{\rho-\rho_0} \qquad r_1 = \frac{\sqrt{n:M}}{\sin Y}$$

For the trial, ρ is taken as the variable.

The trial equation being approximately solved, make

$$\tan 2f'' = \frac{\kappa}{r_1}, \quad r_0 = r_1\sec f'', \quad x = \frac{\theta'^2}{4r_0^3}$$

and X from x by the small table (*A.J.* 206).

For the accurate solution of the trial-equation, now make

$$\kappa^2 r_1 = \frac{2\theta'^2}{X\sec f''}$$

For $\sec f''$ we should write, for perfect precision,
$\cos f''x\sqrt{\sec 2f''}$ here, and above for r_0.

From ρ and $\rho'' = M\rho$, the elements are computed as usual. Should we wish to vary M, we shall only have to repeat the computation of e_0, ρ_0, n, i, and d.

A more accurate value of M will probably be obtained by the expression

$$M = r\frac{b}{a} + \frac{N - rN''}{a\rho}$$

in which ρ and also $r = \dfrac{r''\sin(v''-v')}{r\sin(v'-v)}$ are taken from the orbit as obtained, and

$$N = R''\sin(L''-L'), \quad N'' = R\sin(L'-L).$$

In this we have struck out R' from N and N'', as it has been struck out from a.

This last process, however, will principally be available when we wish to correct the first approximate orbit (for computing which the first value of M will probably amply suffice), by the help of a subsequent observation.

Let this subsequent observation be λ''' β''' &c.

Now let $\quad a = m'''\tan\beta'' - \sin(\lambda''-L''')$

and $\quad b = m'''\tan\beta - \sin(\lambda-L''')$

in which $\quad m''' = \sin(\lambda'''-L''')\cot\beta'''$

$$M = r\frac{b}{a} + \frac{N - rN''}{a\rho}$$

in which $\quad N = R''\sin(L'''-L'') \qquad N'' = R\sin(L'''-L)$

$$r = \frac{r''\sin(v'''-v'')}{r\sin(v'''-v)}$$

the latter, as well as ρ, being obtained from the orbit as computed.

This value of M we simply bring in as a new hypothesis in our previous computation.

It should be remarked that the formula above, $\tan 2f' = \dfrac{\kappa}{r_1}$ of course is by no means an accurate one; it always gives too large a value, the accurate expression being

$$\tan 2f' = \frac{\sqrt{\kappa^2-(r''-r)^2}}{r_1}\cdot\frac{\cos f'}{\sqrt{\cos 2f}}$$

And when $r''-r$ has a considerable value relatively to κ, or in other words, when the comet is far from perihelion, the inaccuracy of course is very marked. But in this case, $2f'$ for a first computation for small intervals will come out very small, even by the formula; and its secant will, after all, not depart so much from the true value. In the example given below, the value of $\sec f'$ by this formula is 0.000036, the true value being 0.000032. In this case the true anomaly is about 39°.

If, however, we should find on beginning the computation of the elements, that $\sec f' = \dfrac{\sqrt{rr''}}{r_1}$ gives a notably different value, another trial can be made in a few moments with this right value and the correct value of ρ obtained. Of course no difficulty will arise when the question is of computing a corrected orbit by means of a new observation in the manner just described; as we shall usually in this case have a sufficiently good value of f' for the purpose.

The following example of Comet a 1890 will show the practical working of this process. The first three observations, reduced to longitude and latitude, are

1890 G.M.T.	λ	β	L	log R
	° ′ ″	° ′ ″	° ′ ″	
Mar. 21.9042	321 57 58	+21 47 2	1 44 40	9.998724
24.0248	322 23 27	+22 35 57	3 50 46	9.998984
24.9039	322 33 54	+22 56 52	4 43 0	9.999092

These give

$e = 1.169155$, $\frac{1}{2}(\varepsilon+\varepsilon'') = +0.613918$, $\log\varepsilon' = 9.929359$, $\log\dfrac{\varepsilon''}{4} = 9.195042$, $g^2 = 0.0026776$, $g' = -0.0008283$, $\log g'' = n8.51950$, $i_0 = +0.0006736$. These are unaffected by changes of M.

The first value of $M = \dfrac{t''-t'}{t'-t}\cdot\dfrac{b}{a}$ is 0.96868, giving

$\mu = +0.06264, \qquad e_0 = +0.008352, \qquad \rho_0 = +0.654048,$
$n = 0.449580, \qquad \log i = 7.07802, \qquad d = -2.4232.$

From these we have $\rho = 2.415$, and the following elements, for 1890.0:

$T =$ June 3.4296 G.M.T.
$\Omega = 320°\ 45'\ 48''$
$\omega = 74\ 0\ 48$
$i = 122\ 0\ 22$
$\log q = 0.251150$

An observation of Mar. 30 afterwards comes in, as follows:

Gr.M.T.	λ	β	L	log R
Mar. 30.8702	323° 46′ 50″	+25° 30′ 25″	10° 36′ 40″	9.999823

The elements, compared with this, give (O—C)

$$\Delta\lambda\cos\beta = +67'' \qquad \Delta\beta = +102''$$

The value of M resulting from this observation with the r and ρ of the previous orbit, is 0.96488.

From this

$\mu = +0.07024, \qquad e_0 = +0.010600, \qquad \rho_0 = +0.655324,$
$n = 0.451369, \qquad \log i = 7.15171, \qquad d = -2.2223.$

These give $\rho = 2.27738$ and the following elements for 1890.0:

$T =$ June 6.6850 G.M.T.
$\Omega = 323°\ 34'\ 35''$
$\omega = 85\ 35\ 14$
$i = 126\ 46\ 21$
$\log q = 0.193624$

These elements give for the observation of Mar. 30 (O—C)

$$\Delta\lambda\cos\beta = +23'' \qquad \Delta\beta = -18''$$

A graphical representation of these discordances, with the previous ones, will show that no materially better representation of this last observation can be obtained with any value of M.

CONTINUATION OF SUN-SPOT OBSERVATIONS,

By WILLIAM DAWSON.

Date	Hour	Wt.	Gp.	Sps.	Notes
1889 Nov. 15	10½	3	0	0	p 100
16	9⅓	2	0	0	p 100
23	8⅔	3	0	0	p 100
25	2½	2	0	0	
30	9	2	0	0	
Dec. 1	9	2	0	0	p 50
2	11½	3	0	0	p 50
6	11½	3	0	0	p 50
8	8⅓	3	0	0	p 50
9	8½	4	0	0	p 100; no faculae
11	11¼	3	1	2	p 50; s 2′ from W edge
12	9	4	1	1	p 50; s larger
13	10⅓	4	0	0	p 100
15	9½	3	0	0	
19	9	3	2	11	p 100; 10 s N of center
21	9	3	2	11	p 50; s prominent
22	9	3	0	0	p 50; s vanished
23	9	3	0	0	p 50; faculae W
24	12	4	1	6	p 100; g S of center
26	9⅓	1	1	18	p 100
27	9	3	2	15	p 50; 1 s at E edge
28	9½	4	2	6	p 100; 1 l s
30	10⅓	2	2	2	p 50; 1 s and fac W edge
31	3	3	1	1	p 50
1890 Jan. 3	12	3	1	1	p 50; 1 s W of center
8	9	1	0	0	p 50
9	9	3	1	2	s in SW quadrant
10	1	4	0	0	p 100
11	3	3	0	0	p 50
12	12⅓	3	0	0	p 50; faculae E and W
14	9⅔	3	0	0	p 50; no faculae
16	12	2	0	0	p 50
17	10	4	1	7	p 100; 2 s with p 50
18	10½	4	1	12	p 100; no faculae
20	3	1	1	4	p 50; g near W side
21	10	3	1	4	p 50; 2 s prominent
22	1½	2	1	1	p 50; s dim at W edge
23	3	3	0	0	p 50; faculae E
24	11½	5	0	0	p 50; hardly any fac
27	9	3	0	0	p 50; faculae W
28	9	1	0	0	p 50
30	11	5	0	0	p 50; no faculae
31	11	4	1	3	p 50; g in NE quadrant
Feb. 4	1	5	0	0	p 100; no faculae
1890 Feb. 8	1	2	0	0	p 50
9	10	3	0	0	p 50
10	12	5	0	0	p 50; no faculae
11	12	5	0	0	p 50; mottle v plain
12	12	3	0	0	p 50
13	11½	5	0	0	p 50; faculae E
14	12		0	0	p 50
15	12		0	0	p 50
16	1	5	1	3	p 50; 2 s white, far N
17	12	4	0	0	p 50; faculae W
21	3	2	0	0	p 50; haze
24	3½	4	0	0	p 50; hardly any fac
Mar. 1	10	3	0	0	p 50
2	12	3	0	0	p 50
3	11	4	1	4	p 100; close to NE edge
4	11	4	1	3	p 50; pen and much fac
6	9½	3	1	4	p 50; 1 s prom
7	1	3	1	4	p 50; 2 s prom 5′ fm N edge
8	10	3	1	5	p 50; 3 s prominent
9	3	3	1	4	p 50; 2 s prom; pen leav
13	10	2	1	2	p 50; s dim, 2′ fm NW edge
14	9	3	1	1	p 50; s dim, much fac
16	9	4	0	0	p 50; a little fac NW
19	9	2	0	0	p 50
21	9½	4	0	0	p 50; but little fac
22	4	4	1	2	p 50; s 4′ fm W edge
23	9	5	0	0	p 50; some fac W
24	3	3	0	0	p 50
25	9½	3	0	0	p 50
26	9	3	0	0	p 50
29	9½	4	0	0	p 50; but little fac
30	9	4	0	0	p 50; hardly any fac
April 1	9	5	0	0	p 50; hardly any fac
2	9	4	0	0	p 50; hardly any fac
3	5	3	0	0	p 50
5	3	4	0	0	p 50; mottle prom
6	11	4	0	0	p 50; mottle prom
7	3	4	0	0	p 50
8	8½	4	0	0	p 50; some fac E
10	4	3	0	0	p 50
11	3	4	2	6	p 50; 5 little s E, 1 s SW
12	8⅓	4	2	10	p 50
13	3	4	2	6	p 100; 2 s with p 50
16	8	3	0	0	p 50

Spiceland, Ind.

OBSERVATIONS OF PAUL'S *ALGOL*-TYPE VARIABLE S *ANTLIAE*,

By PAUL S. YENDELL.

This star, the discovery of whose variability was announced by PAUL, and confirmed by SAWYER in this Journal, no. 214, has been the object of my particular attention since February 13, since which time I have kept it as continuously under observation as the weather has permitted.

The result of the first month's observations satisfied me that the star belonged to the *Algol*-class of variables; but I was not so fortunate as to detect the shortness of its period.

My earlier observations leave something to be desired in the matter of precision, having been made in all weathers when it was possible to observe at all, often in both moonlight and haze; many of these observations have been rejected on this account, in making up the mean light-curve given below.

On April 11 the field-glass observations were supplemented by the use of a small telescope of 1.4-inch aperture, and a power of 14, the field including about three degrees; this was found to be an excellent tool for the work, its light-power being about equal to that of the field-glass, and the greater magnifying power, by separating the stars, renders the comparisons in a marked degree more easy and accurate; the light-scale being sensibly identical. For several evenings observations with this glass were carried on simultaneously with those of the field-glass series, after which the latter instrument was discarded, and the observations made with the small telescope only.

The comparison-stars used are as follows:

		M	L
a =	66 *U.A. Pyxidis*	6.5	10.0
b =	7 " *Antliae*	7.0	5.0
c =	5 " *Antliae*	7.5 (*S.*)	0.6

The star a is noted in the *U.A.* as a suspected variable, but has been sensibly constant during the time covered by these observations; c was adopted on the last evening only when the star was observed, April 25; my estimate of its magnitude agrees closely with Sawyer's, and I have accordingly used the latter in the above table.

The extreme light observed, to which full weight was given, was by this scale 7.75 at normal, and 3.0 at minimum; corresponding respectively to magnitudes $6^{M}.7$ and $7^{M}.2$, and indicating as an extreme light-range of about half a magnitude; these limits are somewhat wider than those indicated by the mean light-curve.

I have obtained in all 171 observations of the star, from which are deduced the following minima; the residuals in the column O—C are derived from a comparison of the observed times with Chandler's elements.

Minima Obtained from Single Light-Curves.

E	Camb. M.T.	w	Light-eqn.	O—C
	h m		m	m
2141	1890 Mar. 8 10 51.5	3	+6.0	—12.8
2246	Apr. 11 9 26.0	5	+4.4	—33.3
2249	12 9 0.0	3	+4.3	—19.8
2285	25 8 40.5	4	+3.2	+ 8.1

Dorchester, 1890 *May* 10.

Minima Deduced by the Mean Light-Curve.

E	1890 Camb. M.T.	w		Light-eqn.	O—C
	h m			m	m
2092	Feb. 20 11 51.0	½	1 observ.	+6.2	+ 0.7
2095	21 10 39.0	½	1 "	+6.2	—21.3
2098	22 9 47.0	½	1 "	+6.2	—41.1
2141	Mar. 9 7 47.0	2	4 "	+6.0	—36.8
2172	18 10 9.0	1	2 "	+5.8	— 5.3
2181	21 8 16.6	2	4 "	+5.7	+ 1.0
2190	24 6 13.5	1	2 "	+5.5	— 3.5
2258	Apr. 15 6 41.3	3	12 "	+4.1	—39.9

The time given for epoch 2258 is the mean of the minima deduced from two simultaneous lines of observations made with the field-glass and small telescope.

The mean by weights of the residuals in the columns O—C is $—12^{m}.4$, corresponding to a mean epoch of 2176.75.

In constructing the mean light-curve, all single-star comparisons having a less weight than 3, and all two-star comparisons whose weight was less than 4, were rejected, as were also all observations which were considered open to doubt on account of the presence of haze or moonlight; there remained available nearly a hundred observations.

Using an ephemeris based on Chandler's elements, these were combined in ten-minute groups, and the curve drawn between the normals thus obtained — due regard being had for the weight of each normal, which represented the sum of the weights of the observations from which it was deduced. The curve thus drawn shows a minimum thirty minutes earlier than the computed epoch, which seems to confirm the indication of the mean residual given above. The whole curve, however, is of course strictly provisional, and will, without doubt, be more or less modified by the results of future observations.

The readings from the mean light-curve are as follows:

h m	Steps	h m	Steps
—2 20	7.00	±0 00	3.84
2 00	6.98	+0 10	3.95
1 40	6.90	0 20	4.25
1 20	6.60	0 40	5.05
1 00	6.10	1 00	5.75
0 40	5.30	1 20	6.26
0 20	4.30	1 40	6.62
—0 10	3.95	2 00	6.86
±0 00	3.84	2 20	6.98
		+2 30	7.00

ELEMENTS AND EPHEMERIS OF COMET *a* 1890 (*BROOKS, March 19*),

By W. W. CAMPBELL.

From the mean of seven European observations of March 23, the mean of two Ann Arbor observations of April 15, and an Ann Arbor observation of May 1, I have computed the following elements and ephemeris of this comet. They give Residuals (O—C), $\cos\beta' \Delta\lambda' = +1''.4$, $\Delta\beta' = -0''.1$.

T = Greenwich M.T. 1890 June 1.46734

$$\left.\begin{aligned} \omega &= \ \ 68^\circ\ 53'\ 44''.6 \\ \Omega &= 320\ \ 20\ \ 53\ .1 \\ i &= 120\ \ 33\ \ 34\ .0 \end{aligned}\right\} 1890.0$$

$\log q = 0.280544$

CONSTANTS FOR THE EQUATOR.

$$x = [9.921947]\ r \sin(181^\circ\ 41'\ 44''.6 + v)$$
$$y = [9.960916]\ r \sin(288\ \ 43\ \ 37\ .1 + v)$$
$$z = [9.834500]\ r \sin(\ 47\ \ \ 4\ \ 12\ .0 + v)$$

EPHEMERIS FOR GREENWICH MEAN MIDNIGHT.

1890	App. α	App. δ	log r	log Δ	Br.
	h m s	° '			
May 10	20 46 33	+37 47.7	0.2849	0.2437	2.92
11	44 36	38 43.1			
12	42 31	39 39.1	0.2842	0.2368	3.03
13	40 19	40 35.7			
14	37 58	41 32.9	0.2835	0.2302	3.13
15	35 28	42 30.5			
16	32 48	43 28.5	0.2829	0.2240	3.23
17	29 59	44 26.8			
18	26 58	45 25.4	0.2823	0.2183	3.33
19	23 47	46 24.2			
20	20 23	47 23.1	0.2819	0.2130	3.42
21	16 46	48 22.0			
22	12 55	49 20.8	0.2815	0.2084	3.49
23	8 50	50 19.4			
24	4 30	51 17.7	0.2811	0.2044	3.56
25	19 59 53	52 15.5			
26	54 59	53 12.8	0.2809	0.2010	3.63
27	49 48	54 9.2			
28	44 17	55 4.7	0.2807	0.1983	3.67
29	38 25	55 59.3			
30	32 12	56 52.7	0.2806	0.1963	3.71
31	25 37	57 44.5			
June 1	18 40	58 31.7	0.2805	0.1951	3.73
2	11 19	59 23.1			
3	3 35	60 9.4	0.2806	0.1946	3.71
4	18 55 26	60 53.5			
5	46 53	61 35.3	0.2807	0.1949	3.73
6	37 56	62 14.3			
7	28 35	62 50.6	0.2809	0.1959	3.71
8	18 18 54	+63 21.0			
June 9	18 8 51	+63 54.2	0.2811	0.1977	3.68
10	17 58 28	64 20.7			
11	47 50	64 43.7	0.2815	0.2004	3.63
12	37 3	65 3.3			
13	25 56	65 19.3	0.2819	0.2033	3.57
14	14 47	65 31.5			
15	3 37	65 40.0	0.2824	0.2071	3.50
16	16 52 28	65 44.9			
17	41 23	65 46.3	0.2829	0.2115	3.42
18	30 28	65 44.1			
19	19 43	65 38.7	0.2835	0.2164	3.34
20	9 15	65 30.1			
21	15 59 1	65 18.5	0.2842	0.2219	3.24
22	49 14	65 4.2			
23	39 45	64 47.2	0.2850	0.2277	3.15
24	30 10	64 27.9			
25	21 57	64 6.5	0.2858	0.2341	3.04
26	13 39	63 43.3			
27	5 45	63 18.1	0.2867	0.2407	2.94
28	14 58 16	62 52.0			
29	51 9	62 24.3	0.2877	0.2477	2.83
30	44 26	61 55.4			
July 1	38 4	61 25.6	0.2887	0.2548	2.73
2	32 4	60 54.9			
3	26 25	60 23.7	0.2898	0.2622	2.62
4	21 5	59 51.8			
5	16 3	59 19.5	0.2910	0.2697	2.52
6	11 20	58 47.0			
7	6 52	58 14.2	0.2922	0.2774	2.42
8	2 40	57 41.2			
9	13 58 43	57 8.1	0.2935	0.2851	2.32
10	55 0	56 35.1			
11	51 30	56 2.1	0.2949	0.2929	2.23
12	48 12	55 29.2			
13	45 5	54 56.5	0.2962	0.3007	2.13
14	42 10	54 24.0			
15	39 26	53 51.7	0.2977	0.3085	2.05
16	36 50	53 19.7			
17	13 34 24	+52 48.0	0.2992	0.3162	1.96

OBSERVATIONS OF VARIABLE STARS IN 1889.

BY EDWIN F. SAWYER.

1. *g Herculis.*

This star was observed on 34 evenings, extending from March 25 to November 20. The observations when charted, notwithstanding the many gaps which occur in the series, permit the determination of two maxima and two minima. The first maximum is indicated about May 18; but with some uncertainty, a bad break occurring between April 21 and May 23. This was followed by a minimum on July 5; the light decreasing very slowly and irregularly. From July 5, the rise was quite rapid, and a second maximum was passed on August 2. A rapid fall occurred, and the second minimum was reached on September 3. After a slight increase the light remained sensibly constant until October 18, followed by another slight rise, the star being apparently near another maximum when the observations terminated on November 20. The fluctuations during the year were not of a marked character, being not over half a magnitude. The interval between the two maxima was 76 days; and between the two minima 60 days.

2. *R Lyræ.*

This star was irregularly observed from 1889 May 28 to 1890 January 9, the observations numbering 40. Maxima are determined for June 7, July 15 and October 23; and minima July 2, November 18 and December 31. No particularly bright phases were recorded.

3. *ρ Persei.*

The observations on this star extend from February 24 to April 7, and from August 27 to 1890 April 16, and number 25. From these two minima have been determined as occurring 1889 November 7, and 1890 March 12.

4. *T Ceti.*

Eleven observations of this star were obtained; extending from 1889 October 16 to 1890 January 16. When first seen *T* was = 21 (*U.A.*) *Ceti*, and 4 steps < 28 and 31 (*U.A.*) *Ceti*, or $7^M.0$; being evidently near minimum. After November 1, the increase was quite rapid and uniform; a maximum being reached on December 13. Maximum brightness 5 steps > 7 (*U.A.*) *Ceti*, and 1 step < 18 (*U.A.*) *Ceti*, or $5^M.5$. The light had decreased about half a magnitude when the observations terminated on January 16. As regards the comparison star 28 (*U.A.*) *Ceti*, alluded to as possibly variable by Father HAGEN (*A. J.* no. 212, p. 158), I can offer no confirmatory evidence from my observations, although it has been less used than the star 31 (*U.A.*) *Ceti*, of about the same magnitude. The star was observed once in 1884, and three times in 1886, in connection with my revision of the *Uranometria Argentina* magnitudes; the range of the four observations being from $6^M.5$ to $6^M.7$, and the average $6^M.6$, which agrees very nearly with the *U.A.* results, $6^M.5$. The star will, however, bear further watching.

5. *U Ceti.*

This star was observed from January 14 to February 21, 1890, 14 observations being obtained. When first seen, on January 14, *U* was = SDM. 13° 483, or $8^M.8$. The increase of light was very rapid and uniform, a maximum being reached February 7.5. Its maximum brightness was 4 steps > SDM. 13° 495, and 4 steps < SDM. 13° 457, or $7^M.1$. When last seen, on February 21, *U* had faded 3 or 4 steps.

6. *U Orionis.*

The observations on this star number 27, and extend from 1889 November 25 to 1890 March 8. When first seen, on November 25, *U* was 4 steps < DM. 20° 1168, or about $9^M.0$. The increase appeared quite rapid and uniform, a maximum being passed 1890 January 6. Maximum brightness 4 steps > DM. 19° 1106, 1 or 2 steps > DM. 20° 1156, and 5 steps < DM. 19° 1110, or $6^M.7$. The light remained stationary for 28 days. The decrease was slow, and very regular. When last observed, on March 8, *U* was = DM. 20° 1168, or $8^M.6$. The interval between the last two maxima was 376 days.

7. *S Serpentis.*

A few scattering observations of this star, 8 in number, extending from March 25 to May 23, indicate a maximum as occurring about April 24, but this time may be in error by several days. When brightest, *S* was 1 step < DM. 15° 2845, or about $7^M.4$.

8. *W Cygni.*

Observed from 1889 February 19 to 1890 February 20, 50 observations. The observations during the first three months are scattering, yet permit of a maximum being fairly determined for March 11. The decrease after March 11 was slow, and a rather faint minimum was passed about May 29. After a very slow and irregular rise a second and faint maximum was reached on August 22. A second and rather bright minimum was passed on October 9. A third maximum was reached on November 14, followed by a faint minimum 1890 January 29. The interval between the first and second maxima was 161 days, while between the second and third maxima the interval is only 84 days. The interval between the first and second minima is 133 days, and between the second and third minima 112 days.

Brighton, 1890 *May* 24.

OBSERVATIONS OF COMET *a* 1890 (*BROOKS*).

MADE AT THE U.S. NAVAL OBSERVATORY WITH THE 9.6-INCH EQUATORIAL.

BY PROF. E. FRISBY.

[Communicated by the Superintendent.]

1890 Washington M.T.	*	No. Comp.	☄ — * $\Delta\alpha$	☄ — * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
d h m s			m s	′ ″	h m s	° ′ ″		
Mar. 26 16 45 5.4	1	15 , 3	−1 25.73	−0 21.6	21 10 30.15	+ 8 32 16.9	n9.612	0.697
Apr. 1 16 39 35.6	2	8 , 2	+4 12.41	−1 41.0	21 11 5.90	+11 17 58.3	n9.595	0.671
16 39 35.6	3	10 , 2	+3 12.10	−1 24.1	21 11 6.30	+11 17 56.0		
2 16 49 54.1	4	6 , 2	−0 21.50	−3 48.9	21 11 8.06	+11 48 27.9	n9.578	0.660
19 10 12 58.7	5	9 , 2	−0 22.75	−3 19.1	21 8 9.46	+21 24 9.7	n9.693	0.713
10 12 58.7	6	9 , 2	−2 13.87	+5 8.4	21 8 10.16	+21 24 15.3		
21 13 7 58.7	7	20 , 4	−0 21.18	+1 38.5	21 7 10.39	+22 44 29.5	n9.698	0.705

Mean Places for 1890.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	21 11 57.04	—1.16	+ 8 32 51.7	—13.2	Weisse's Bessel, XXI 216
2	21 6 54.48	—0.99	+11 19 52.3	—13.0	⅓(Weisse's Bessel + 2 Grant)
3	21 7 55.19	—0.99	+11 19 33.1	—13.0	Weisse's Bessel, XXI 108
4	21 11 30.57	—1.01	+11 52 29.9	—13.1	Bonn Obs., VI, +11° 4528
5	21 8 32.76	—0.55	+21 27 43.7	—14.9	Weisse's Bessel, XXI 148
6	21 10 24.59	—0.56	+21 19 21.7	—14.8	Weisse's Bessel, XXI 196
7	21 7 32.05	—0.48	+22 13 6.0	—15.0	Weisse's Bessel, XXI 117

OBSERVATIONS OF COMET *a* 1890 (*BROOKS*),

MADE AT THE WASHBURN OBSERVATORY WITH THE 15.5-INCH EQUATORIAL,

By A. S. FLINT.

[Communicated by Prof. COMSTOCK, Director.]

1890 Madison M.T.	*	No. Comp.	☄ — * Δα	☄ — * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
d h m s			m s	′ ″	h m s	° ′ ″		
Apr. 10 16 19 42.6	1	18	+1 6.81		21 10 42.60		*n*9.555	
17 16 10 56.1	2	18 , 3	—0 36.08	+4 55.6			*n*9.533	0.618
19 16 11 1.2	3	18 , 3	—0 27.33	+3 8.7	21 8 4.89	+21 30 37.4	*n*9.528	0.598
20 15 56 30.6	4	6	+0 48.03				*n*9.408	
16 8 33.8	4	3		—2 54.9				0.547
26 15 44 55.0	5	36 , 5	—0 24.82	—6 32.4	21 3 50.67	+26 25 40.8	*n*9.526	0.522

Mean Places for 1890.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	21 9 36.57	—0.78	. . . .	. . . .	¼(W.B., XXI 161) 2 Armagh, II 2792 Rümker, 9043
2	21 9 31.0	—0.59	+20 7.1	—14.6	DM., 19° 4661
3	21 8 32.76	—0.54	+21 27 43.6	—14.9	W.B., XXI 148
4	21 6 49.4	—0.50	+22 14.2	—15.0	D.M., 22° 4329
5	21 4 15.78	—0.29	+26 32 28.7	—15.6	½(W.B., XXI 33, 34 + Rümker 8935)

The comparisons in R.A. for April 26 were made by eye and ear, the others with a chronograph.

OBSERVATIONS OF COMET *a* 1890 (*BROOKS*),

MADE WITH THE 6-INCH EQUATORIAL OF THE DETROIT OBSERVATORY (ANN ARBOR).

By W. W. CAMPBELL.

1890 Greenwich M.T.	*	No. Comp.	☄ — * Δα	☄ — * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ	
d h m s			m s	′ ″				
Apr. 11 21 13 33	9	7	+2 25.24	+5 23.0	21 10 33.02	+16 33 7.1	*n*9.607	0.682
15 21 6 9	10	12 , 7	—0 49.18	+6 20.5	21 9 35.76	+18 55 38.1	*n*9.603	0.657
21 6 9	11	11	—2 4.88	+1 36.7	21 9 36.01	+18 55 35.5	*n*9.603	0.657
16 20 37 17	12	11 , 7	+3 48.41	+1 39.3	21 9 16.20	+19 32 8.1	*n*9.627	0.671
18 20 22 28	13	15 , 14	+0 29.00	—1 52.4	21 8 32.24	+20 48 14.2	*n*9.637	0.667
20 22 28	14	14 , 11	—0 12.96	+3 56.0	21 8 32.73	+20 48 15.6	*n*9.637	0.667
20 20 36 5	15	10 , 15	+2 1.71	+7 51.6	21 7 59.02	+22 8 1.6	*n*9.620	0.647
May 1 19 26 1	16	15	+1 19.54	+0 27.4	20 59 16.79	+30 15 16.2	*n*9.668	0.582

Mean Places for 1890.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
9	21 8 8.53	—0.75	+16 27 58.3	—13.9	$\frac{1}{3}$(W.B., 21^h 114 + Rü. 9004 + Lam_6 1096)
10	21 10 25.56	—0.62	+18 49 32.3	—14.4	$\frac{1}{3}$(W.B., 21^h 195 + Rü. 9058 + Lam_6 1114)
11	21 11 41.51	—0.62	+18 54 13.2	—14.4	$\frac{1}{2}$(W.B., 21^h 229 + Lam_6 1121)
12	21 5 28.35	—0.59	+19 30 43.4	—14.6	Armagh_2 2782
13	21 8 3.80	—0.56	+20 50 21.1	—14.8	$\frac{1}{2}$(Rü. 9003 + Lam_6 1094)
14	21 9 16.26	—0.57	+20 44 34.4	—14.8	$\frac{1}{3}$(2 Rü. 9036 + Lam_6 1106)
15	21 5 34.80	—0.49	+22 0 24.7	—14.7	Glasgow, 5378
16	20 57 57.20	—0.12	+30 15 4.9	—16.1	W.B., 20^h 1761

April 11, Comet very faint through haze. May 1. Comet very faint in moonlight.

NEW ASTRONOMICAL WORKS.

Second Melbourne General Catalogue of 1211 Stars, for the Epoch 1880.

The First Melbourne General Catalogue, published in 1874, contained the positions of 1227 stars, deduced from observations made previous to 1871.

This second one gives, like the former, the results of observations made with the 5-inch transit-circle at the Melbourne Observatory, under the direction of Mr. Robert L. J. Ellery, and reduced and prepared for publication by the first assistant astronomer, Mr. E. J. White. It contains the positions determined between the beginning of 1871 and the end of August 1884, at which date the new 8-inch transit-circle was mounted. Thus the positions here given are deduced from those published in vols. V, VI and VII of the Melbourne Observations.

For this purpose, weights corresponding to the number of observations have been assigned to the coordinates, given in the several annual volumes, after these were referred to the equinox of 1880.0, using terms of the third order in the precessions. But where, as in a majority of cases, a value has been adopted for the proper motion, the places for 1880.0 have been correspondingly modified. And furthermore, since the north polar distances in the annual catalogues were obtained by employment of the latitude 37° 49′ 53″.4 and of Bessel's refractions, these have, for the sake of uniformity with the First Catalogue, been here modified by the corrections proposed by Mr. Stone in 1867.

Most of the stars south of the tropics are Lacaille's, — the remainder being apparently such as have been used for comparison with comets.

Handbuch der Astronomie, ihrer Geschichte, und Litteratur, von Dr. Rudolf Wolf. *Erster Abschnitt.* Zürich, 1890.

This, the first part of Professor Wolf's eagerly awaited Handbook of Astronomy, contains the first of the four "books" of which the work is to consist. It is entitled "*Aufgabe, Geschichte, und Vorkenntnisse*," and begins with a full table of the contents of the entire publication, which comprises 640 sections, 160 of them being in the first half volume. Book second is entitled *Einleitung in die Astronomie;* Book third, *Theorie der Instrumente und Messungen;* and Book fourth, *Mechanik und Physik des Himmels.*

The peculiarly encyclopedic character of Prof. Wolf's previous works will have led the students and lovers of astronomy to expect the same thorough and exhaustive character in this; and an inspection of the table of contents shows that they will not be disappointed, either in the vast amount of historic information given, or in the wide range of knowledge comprised within the author's interpretation of his subject.

In his preface the author says that the work is designed for the use both of beginners in the science and of astronomers. For the former it points out the path which experience has shown to be requisite for those who desire to become astronomers, in the true sense of the word; while, for the latter, it is intended to obviate, in some degree, the need of frequent consultation of their libraries, as well as serve as a convenient book of reference, where technical and historical data are compactly arranged, which else would have to be sought through hundreds of volumes. A collection of tables is to be given at the end of the first volume, and an elaborate General Index at the end of the second.

We can imagine no more complete and concise summary of the principal facts in astronomical history and science, than these two volumes promise, and the distinguished author's name is a voucher for their accuracy.

NEW ASTEROID.

A small planet was discovered by Charlois, at Nice, in the position

1890 May 20.5784 Greenwich M.T. $\alpha = 16^h\ 20^m\ 55^s.1$, $\delta = -22°\ 39'\ 2''$.

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INVESTIGATION OF ERRORS IN LACAILLE'S *COELUM AUSTRALE STELLIFERUM*,

BY B. A. GOULD.

IV.

Catalogue-position. No.	R.A.	N.P.D.	C. A.		Arg. Gen. Catal. for Equinox 1750.0 No.	Mag	α	δ
	h m s	° ′ ″	page				h m s	° ′ ″
6808	16 7 6.6	164 56 8	21	Nos. 6608 and 6641 are clearly the same star; but I see no way of harmonizing the observations except by supposing the egress of the former to have been 5s later, and the ingress of the latter 10s earlier than recorded. These assumptions give the positions 6808 16h 7m 10s.0, 74° 55′ 48″ 6811 16 7 9 .3, 74 55 29	22337	7½	16 7 7.1	74 51 58
6811	16 7 15.6	164 54 31	17					
6828	16 9 10.7	171 50 23	9	Assume ingress at 16 10 13 instead of 16 0 13, which gives the position 16h 19m 10s.7, 81° 50′ 23″. In the British edition 10m was wrongly subtracted from the egress.	22775	7	16 19 2	81 51 55
M 6849	16 12 31.6	115 6 19	135	Assume egress at 16 15 14 instead of 16 14 14, which gives the position 16h 13m 5s.1, 24° 52′ 38″	22296	7	16 13 4.1	24 52 11
6878	16 17 24.6	121 1 11	117	This appears to be an observation of no. 6875, recorded on p. 125, two days later, but I cannot explain the discordance.	22385	7½	16 17 8.0	30 59 32
6892	16 20 8.1	157 19 16	29	Assume ingress at 16 17 37 instead of 16 16 37, which gives the position 16h 20m 38s.7, 67° 13′ 39″	22561	7½	16 20 38.1	67 11 4
6915	16 23 8.1	137 23 20	81	Assume ingress at 16 20 57 instead of 16 21 57, which gives the position 16h 22m 39s.0, 47° 13′ 7″	22530	7¾	16 22 39.4	47 13 24
6917	16 23 21.3	135 0 13	81	Interchanging the ingresses of nos. 6917 and 6929, we find the positions 16h 23m 49s.6, 44° 50′ 32″ 16 24 53 .9, 45 33 21	22556	7	16 23 49.6	44 50 53
6929	16 25 22.3	135 23 53			22574	6½	16 24 55.5	45 33 34
6948	16 27 6.3	165 41 38	17	Assume egress at 16 33 12 instead of 16 33 22, which gives the position 16h 27m 1s.9, 75° 43′ 29″	22770	6¾	16 27 0.5	75 15 33
A 6951	16 27 11.1	120 44 19	125	Assume ingress at 16 27 0 instead of 16 27 5, which gives the position 16h 27m 38s.5, 30° 43′ 15″	22609	7½	16 27 38.8	30 43 30
M 6977	16 30 59.6	121 0 16	125	Assume ingress at 16 30 51 instead of 16 31 1, which gives the position 16h 30m 54s.6, 30° 58′ 8″	22670	8	16 30 55.0	30 58 13
6979	16 31 31.5	147 2 5	57	Assuming ingress of no. 6979 at 16 26 14 instead of 16 26 19, and interchanging egresses with no. 6985, we have the positions 16h 31m 10s.9, 57° 6′ 21″ 16 32 56 .5, 57 26 50	22723	7	16 31 9.8	57 6 46
6985	16 32 38.4	147 31 12			22760	6½	16 32 53.8	57 26 55
6990	16 33 2.8	162 10 35	21	Is the same star as no. 6988.	22886	7½	16 32 57.7	72 10 32
6994	16 33 35.4	143 59 10	63	Error of 20s in the British reduction. The place should be given as 16h 33m 55s.4, 53° 59′ 10″	22780	7½	16 33 56.2	53 59 2
A 7033	16 37 54.5	120 7 38	125	Assume ingress at 16 31 53 instead of 16 35 53, and interchange egresses with no. 7041. Then we have 16h 37m 15s.8, 29° 58′ 25″ The series of observations made in the lower part during the interval 16h 35m to 16h 40m, 1752 June 18, is almost hopelessly confused. No one of the four successive stars 7033, 7037, 7041, 7051, exists in the sky. The changes here suggested are sweeping; yet the obstructions cannot be disentangled and reconciled without changes equally great. Those suggested for nos. 7033 and 7041 are identical with ARGELANDER'S. See his remarks Bonn Obs., VII. 241 2.	22811	7½	16 37 11.9	29 58 58

Catalogue-position.			C.A.		Arg. Gen. Catal. for Equinox 1750.0			
No.	R.A.	N.P.D.			No.	Mag	α	δ
	h m s	° ′ ″	page				h m s	° ′ ″
7037	16 38 16.7	120 19 12	125	Assume both moments 5^{s} earlier than recorded, which gives the position $16^{h}\ 38^{m}\ 11^{s}.7$, 30 19′ 13″	22840	7½	16 38 11.7	30 18 41
A 7041	16 38 43.2	120 36 11	125	Assume ingress at 16 37 45 instead of 16 37 50. Then with the egress recorded for no. 7033, we obtain the position $16^{h}\ 38^{m}\ 49^{s}.8$, 30 32′ 3″	22863	7½	16 38 49.5	30 32 27
7043	16 39 8.2	115 21 26	135	Assume egress at 16 40 5 instead of 16 40 15, which gives the position $16^{h}\ 39^{m}\ 3^{s}.2$, 25 23′ 11″	22861	7	16 39 1.3	25 23 24
7054	16 39 54.9	120 39 51	125	The place of this fictitious star appears to result from the ingress of no. 7044, and the egress of G.C. 22859, which took place within 1^{s} of the moments here recorded. The former star was observed two days previously; the latter is **Piazzi** 215, $6\frac{1}{2}^{M}$, not otherwise observed by **Lacaille**.				
M 7058	16 40 23.7	120 54 45	125	Assume ingress at 16 40 2 instead of 16 40 12, which gives the position $16^{h}\ 40^{m}\ 18^{s}.8$, 30 52′ 36″	22915	7¼	16 40 17.5	30 52 38
7063	16 41 26.1	122 36 52	117	Assume egress at 16 43 26 instead of 16 44 26, which gives the position $16^{h}\ 40^{m}\ 55^{s}.8$, 32° 49′ 41″. The star is *F. 27 Scorpii.*	22931	6	16 40 56.0	32 50 6
A 7070	16 42 58.1	115 40 40	135	Assume ingress at 16 43 10 instead of 16 43 19, which gives the position $16^{h}\ 42^{m}\ 53^{s}.7$, 25 38′ 38″	22967	8	16 42 54.0	25 38 38
M 7096	16 46 44.3	121 26 26	117	Assume ingress at 16 46 51 instead of 16 45 51, which gives the position $16^{h}\ 47^{m}\ 14^{s}.9$, 31° 13′ 41″	23069	7¼	16 47 13.9	31 13 34
M 7114	16 48 58.6	115 27 9	134	Interchanging moments of egress of 7114 and 7116, we find the positions $16^{h}\ 48^{m}\ 40^{s}.8$, 25° 18′ 57″ *F 28 Ophiuchi* 16 49 24.0, 25 15 47 *F 31 Ophiuchi*	23092	6¾	16 48 39.4	25 18 56
M 7116	16 49 6.3	115 7 36			23106	6¾	16 49 22.6	25 15 53
M 7128	16 50 7.7	118 27 54	125	Assume egress at 16 50 53 instead of 16 50 43, which gives the position $16^{h}\ 50^{m}\ 12^{s}.7$, 118 30′ 6″	23131	7½	16 50 12.3	28 30 4
7194	17 0 6.1	136 21 15	81	Assume egress at 17 2 25 instead of 17 2 20, which gives the position $17^{h}\ 0^{m}\ 8^{s}.7$, 46° 20′ 21″. There is a proper motion of about $+0^{s}.088$ and $+0''.04$, which is used in reducing the Gen. Catalogue positions to 1750 Using the same for Br. 6022 we obtain $17^{h}\ 0^{m}\ 8^{s}.8$, 46° 20′ 27″	23397	6	17 0 8.8	46 20 28
M 7248	17 6 19.3	119 38 59	125	Wrongly reduced in British edition. The place should be given as $17^{h}\ 6^{m}\ 16^{s}.9$, 31° 2′ 22″	23499	8¼	17 6 15.8	31 1 14
7277	17 9 22.8	133 20 39	91	Assume ingress at 17 5 52 instead of 17 5 32, which gives the position $17^{h}\ 9^{m}\ 33^{s}.1$, 43 17′ 8″	23608	7½	17 9 33.6	43 17 19
M 7296	17 11 31.2	116 0 49	129	Assume ingress at 17 10 17 instead of 17 10 37, which gives the position $17^{h}\ 11^{m}\ 21^{s}.3$, 26 5′ 17″	23620	7¾	17 11 20.8	26 5 4
A 7306	17 13 11.6	129 54 54	125	Assume the minute as 12 instead of 13 for each transit, and egress at 17 12 36 instead of 17 12 51. This gives the position $17^{h}\ 12^{m}\ 4^{s}.0$, 30° 58′ 6″	23644	8¾	17 12 5.2	30 57 59
M 7341	17 17 17.2	119 22 20	125	Assume egress at 17 14 40 instead of 17 15 0, which gives the position $17^{h}\ 17^{m}\ 7^{s}.1$, 29° 26′ 37″ See, however, **Argelander's** remarks, Bonn Obs. VII 242	23777	7	17 17 8.3	29 26 23
M 7345	17 18 22.8	122 19 52	117	Reducing for the lower part we have the position $17^{h}\ 18^{m}\ 24^{s}.2$, 32° 22′ 14″	23811	5¾	17 18 23.9	32 22 45
7352	17 19 32.8	128 11 28	105	Assume egress at 17 23 32 instead of 17 22 2, which gives the position $17^{h}\ 20^{m}\ 19^{s}.3$, 37° 53′ 22″	23855	6¾	17 20 20.4	37 52 41
M 7411	17 27 34.1	119 59 19	125	Assume egress at 17 30 10 instead of 17 30 20, which gives the position $17^{h}\ 27^{m}\ 29^{s}.0$, 30° 1′ 30″	24014	7½	17 27 29.5	30 1 40
7441	17 32 3.0	122 35 25	117	Assume ingress at 17 29 20 instead of 17 29 35, which gives the position $17^{h}\ 31^{m}\ 55^{s}.6$, 32° 32′ 12″. If we assume ingress at 17 29 23 we should have $17^{h}\ 31^{m}\ 57^{s}.1$, 32° 32′ 50″	24139	7¼	17 31 55.9	32 32 57
7464	17 35 2.4	124 53 47	111	Assume ingress at 17 32 43 instead of 17 31 43, which gives the position $17^{h}\ 35^{m}\ 33^{s}.1$, 34° 41′ 40″	24240	7¼	17 35 34.3	34 42 4
M 7469	17 36 13.3	121 11 35	117	Assume ingress at 17 35 45 instead of 17 35 55, which gives the position $17^{h}\ 36^{m}\ 8^{s}.3$, 31° 13′ 42″	24245	7½	17 36 6.6	31 13 54
A 7491	17 39 29.3	114 47 15	134	Assume ingress at 17 37 55 instead of 17 37 50, which gives the position $17^{h}\ 39^{m}\ 31^{s}.7$, 24° 48′ 24″	24312	6½	17 39 31.4	24 48 34
M 7532	17 45 7.4	160 40 42	23	Assume egress at 17 53 12 instead of 17 52 12, which gives the position $17^{h}\ 45^{m}\ 37^{s}.0$, 70° 45′ 16″	24646	6½	17 45 38.5	70 45 4

Catalogue-position.			C. A.		Arg. Gen. Catal. for Equinox 1875.0			
No.	R.A.	N.P.D.			No.	Mag	α	δ
	h m s	° ′ ″	page					
B 7553	17 49 7.1	151 32 40	41	Assume ingress at 17 42 28 instead of 17 46 28, which gives the position $17^{h}\ 47^{m}\ 8^{s}.4$, 62° 0′ 6″. The true *ι Pavonis.*	24618	5¾	17 17 10.4	62 0 8
7597	17 54 59.6	131 32 39	99	Assume egress at 17 56 59 instead of 17 55 59, which gives the position $17^{h}\ 55^{m}\ 31^{s}.2$, 41° 21′ 16″	21763	6¼	17 55 50.7	41 21 45
7600	17 55 32.6	131 56 27	99	The same error of 1^{m} was made in both transits of this star, as in the egress of the preceding. Substituting 56 for 55, we have the position $17^{h}\ 56^{m}\ 32^{s}.7$, 41° 56′ 28″	24787	7¼	17 56 32.6	41 56 30
A 7634	17 59 13.4	119 48 1	125	Assume egress at 18 2 10 instead of 18 2 25, which gives the position $17^{h}\ 59^{m}\ 5^{s}.8$, 29° 51′ 19″	24829	6¼	17 59 5.2	29 51 56
7678	18 5 58.9	161 28 19	23	Assume ingress at 18 0 10 instead of 18 0 30, which gives the position $18^{h}\ 5^{m}\ 49^{s}.1$, 71° 26′ 39″	25177	7¼	18 5 46.6	71 26 45
M 7693	18 8 16.7	122 18 52	117	Reducing for the lower part, we have the position $18^{h}\ 8^{m}\ 18^{s}.1$, 32° 23′ 46″	25074	7¼	18 8 17.8	32 23 27
7715	18 11 27.1	138 18 33	75	Assume ingress at 18 9 22 instead of 18 8 22, which gives the position $18^{h}\ 11^{m}\ 58^{s}.5$, 48° 8′ 46″	25209	7¼	18 11 58.3	48 8 39
7783	18 20 30.3	146 26 33	57	Assume egress at 18 22 6 instead of 18 23 26, which gives the position $18^{h}\ 19^{m}\ 51^{s}.7$, 56° 15′ 41″. Diminishing ingress also by 5 seconds would make the accordance complete.	25422	7¼	18 19 48.5	56 16 22
7792	18 21 47.3	149 1 21	47	I cannot reconcile these observations with any star now in the sky except by changing both moments. Assume ingress at 18 17 19 instead of 18 17 34 and egress at 18 24 30 instead of 18 23 30 and we have the position $18^{h}\ 22^{m}\ 9^{s}.0$, 59° 10′ 42″	25501	8	18 22 10.0	59 10 51
A 7803	18 22 51.9	120 42 29	125	Wrongly reduced in British edition. The place should be given as $18^{h}\ 22^{m}\ 49^{s}.4$, 30° 42′ 30″	25431	8	18 22 48.2	30 12 20
7812	18 23 55.0	129 15 27	99	Assume ingress at 18 23 3 instead of 18 23 13, which gives the position $18^{h}\ 23^{m}\ 49^{s}.7$, 39° 17′ 23″	25482	8¼	18 23 49.2	39 17 4
7871	18 33 36.5	124 47 47	111	Assume ingress at 18 31 42 instead of 18 30 32, which gives the position $18^{h}\ 34^{m}\ 12^{s}.3$, 34° 33′ 36″	25738	7½	18 31 13.9	34 33 42
A 7898	18 36 39.9	121 0 10	117 125	Wrongly reduced in British edition. The mean of the places should be given as $18^{h}\ 36^{m}\ 38^{s}.2$, 31° 0′ 10″	25806	6¾	18 36 37.7	31 0 10
7946	18 43 39.4	123 41 47	117	I cannot explain this observation. The magnitude 6½ implies that the star was comparatively bright; yet I find none within the limits of the zone to which the record of either transit seems applicable.				
7969	18 47 20.9	157 37 45	29	The egress is evidently recorded 2^{m} too early. If in addition to this we assume the ingress at 18 42 10 instead of 18 42 15, we have the position $18^{h}\ 48^{m}\ 17^{s}.2$, 67° 48′ 56″	26203	7¼	18 48 19.2	67 19 11
7971	18 47 43.5	152 12 27	41	Assume ingress at 18 47 41 instead of 18 42 41, which gives the position $18^{h}\ 50^{m}\ 15^{s}.4$, 63° 17′ 42″	26214	7	18 50 10.8	63 17 36
7985	18 49 23.0	124 3 49	111	Assume ingress at 18 47 44 instead of 18 48 1, which gives the position $18^{h}\ 49^{m}\ 12^{s}.9$, 34° 7′ 56″	26108	7¾	18 49 12.8	34 7 15
A 7996	18 51 49.4	119 1 51	125	Assume egress at 18 53 32 instead of 18 53 42, which gives the position $18^{h}\ 51^{m}\ 44^{s}.1$, 28° 59′ 41″	26161	6½	18 51 45.2	28 59 41
8020	18 55 4.4	165 39 23	15	Assume ingress at 18 51 37 instead of 18 51 7, which gives the position $18^{h}\ 55^{m}\ 19^{s}.6$, 75° 35′ 53″	26454	7½	18 55 19.7	75 36 15
8031	18 57 16.8	163 22 52	19	Assume egress at 19 2 25 instead of 19 1 25, which gives the position $18^{h}\ 57^{m}\ 45^{s}.5$, 73° 30′ 46″	26173	7¼	18 57 46.6	73 31 27
8046	18 59 25.1	164 24 36	19	Assume ingress at 18 57 29 instead of 18 57 14, which gives the position $18^{h}\ 59^{m}\ 33^{s}.2$, 74° 26′ 41″. Another observation of Lac. 8048.	26534	7½	18 59 33.0	74 26 3
8066	19 2 48.4	123 45 16	117	Assume ingress at 19 2 53 instead of 19 3 8, which gives the position $19^{h}\ 2^{m}\ 40^{s}.9$, 33° 42′ 10″	26425	7½	19 2 40.6	33 44 19
8106	19 10 34.7	145 46 28	57	Assume egress at 19 16 58 instead of 19 10 58, which gives the position $19^{h}\ 13^{m}\ 28^{s}.7$, 56° [illegible] 36″	26734	7	19 13 28.7	56 [illegible] 19
8171	19 22 10.7	162 15 55	19	I cannot explain this observation.				
8179	19 24 9.8	169 32 24	11	Assume egress at 19 29 30 instead of 19 28 10, which gives the position $19^{h}\ 24^{m}\ 36^{s}.1$, 79° 27′ 21″	27191	7¼	19 24 36.7	79 26 35
8181	19 24 15.6	169 29 23	11	Assume egress at 19 30 30 instead of 19 29 30, which gives the position $19^{h}\ 25^{m}\ 17^{s}.2$, 79° 23′ 15″	27202	7¼	19 25 11.7	79 23 11

Catalogue-position.			C. A.		Arg. Gen. Catal. for Equinox 1750.0			
No.	R.A.	N.P.D.			No.	Mag	α	δ
	h m s	° ′ ″	page				h m s	° ′ ″
8203	19 28 41.6	162 38 44	19	Assume ingress at 19 26 8 instead of 19 26 38, which gives the position 19^h 28^m 26^s.1, 72° 43′ 4″	27157	7¾	19 28 29.3	72 43 6
M 8225	19 32 32.1	118 56 10	125	Interchanging the times of egress, we have the positions 19^h 32^m 13^s.0, 29° 4′ 24″ 19 33 33 .0, 29 22 41	27097	7	19 32 13.7	29 4 47
M 8232	19 33 13.7	119 30 53			27120	6¼	19 33 34.2	29 22 54
8246	19 35 58.7	127 18 11	105	Assume ingress at 19 37 17 instead of 19 32 17, which gives the position 19^h 38^m 33^s.7, 36° 49′ 24″	27245	7	19 38 33.2	36 49 37
8276	19 41 28.6	132 28 19	93	Lacaille's observation is correctly reduced. The position of Gen. Catal. 27305 may possibly be erroneous, for it depends only on one observation: but the other two stars were repeatedly observed. No. 27306 is too faint for probable identity; and the R.A. of no. 27312 differs from Lacaille's by 25^s. Such proper motion as this would imply is contradicted by the Gen. Catalogue. The supposition of an error of 25^s at both moments is not plausible, for the egress of Lac. 8286 was correctly noted during the interval.	27305	8	19 41 26.5	42 29 26
					27306	9¼	19 41 32.0	42 28 35
					27312	7¾	19 41 53.6	42 28 33
8305	19 45 32.2	131 53 20	93	Wrongly reduced in British edition. The place should be given as 19^h 45^m 32^s.2, 42° 4′ 28″	27411	7½	19 45 30.6	42 4 58
8311	19 46 54.3	145 44 48	57	I find no star reconcilable with Lacaille's record here. Adding 1^m to each transit, we have a decided similarity with the observation of Lac. 8337 in the upper part.				
M 8324	19 48 52.3	151 34 3	41	Assume egress at 19 57 15 instead of 19 51 15, which gives the position 19^h 51^m 54^s.3, 62° 14′ 50″	27598	7	19 51 55.9	62 15 40
8344	19 51 42.3	134 42 0	93	Assume egress at 19 52 10 instead of 19 51 40, which gives the position 19^h 51^m 58^s.1, 44° 36′ 38″	27549	7	19 51 57.2	44 36 59
M 8345	19 51 43.2	154 11 26	35	Assume ingress at 19 50 0 instead of 19 49 30, which gives the position 19^h 51^m 58^s.5, 64° 8′ 15″	27609	6½	19 51 56.6	64 7 19
8348	19 52 24.4	134 31 28	93	Assume ingress at 19 52 7 instead of 19 51 42, which gives the position 19^h 52^m 36^s.2, 44° 35′ 57″	27562	6½	19 52 36.7	44 35 49
8361	19 54 28.6	138 6 8	75	Assume egress at 19 58 24 instead of 19 56 24, which gives the position 19^h 55^m 25^s.3, 48° 25′ 41″	27641	6¾	19 55 25.6	48 25 53
8362	19 54 43.4	126 42 18	105	Assume egress at · 19 55 17 instead of 19 55 2, which gives the position 19^h 54^m 50^s.7, 36° 45′ 17″	27600	5¾	19 54 47.4	36 45 31
A 8429	20 9 27.6	120 56 45	121	Assume egress at 20 10 51 instead of 20 10 4, which gives the position 20^h 9^m 51^s.4, 30° 46′ 37″	27969	7½	20 9 51.1	30 46 17
8460	20 13 57.1	174 24 10	3	I cannot explain this observation without arbitrary assumption of errors of record in both transits.				
8467	20 15 50.6	160 43 4	23	Lacaille gives the magnitude as 6, but the only star with which his observation can now be reconciled is 8^M. For this it is necessary to assume the seconds of ingress as 40 instead of 4, and the minute of egress as 22 instead of 23. These changes would give the position 20^h 15^m 39^s.1, 70° 35′ 42″	28204	8	20 15 40.2	70 36 6
8493	20 19 30.8	166 48 1	15	Assume ingress at 20 13 55 instead of 20 14 55, which gives the position 20^h 19^m 1^s.4, 76° 40′ 34″	28362	7¾	20 19 1.2	76 42 6
A 8556	20 31 33.4	114 42 29	137	Wrongly reduced in British edition. The place should be given as 20^h 31^m 33^s.7, 24° 37′ 53″	28464	7	20 31 33.2	24 36 50
8565	20 32 17.9	144 40 54	63	Error of 10 minutes in British edition. The place should be given as 20^h 42^m 18^s.0, 54° 40′ 54″	28736	7¼	20 42 15.4	54 41 9
M 8575	20 34 4.4	118 16 47	131	The minute for both ingress and egress should be 35 instead of 34, giving the position 20^h 35^m 4^s.4, 28° 16′ 47″	28557	7¼	20 35 3.0	28 16 25
M 8589	20 35 33.3	118 9 31	131	The minutes for ingress and egress should be 36 and 37 instead of 35 and 36, giving the position 20^h 36^m 33^s.3, 28° 9′ 31″	28593	6¾	20 36 33.1	28 9 28
A 8601	20 36 50.5	117 49 59	131	The minute at ingress should be 35 instead of 34, giving the position 20^h 36^m 51^s.5, 27° 49′ 59″. Corrected in British edition, where is an error of 1^s.	28598	4	20 36 50.9	27 50 3
8643	20 46 9.2	171 11 3	7	Assume egress at 20 49 40 instead of 20 50 40, which gives the position 20^h 45^m 40^s.3, 81° 6′ 49″	29062	7½	20 45 51.2	81 6 52
8674	20 49 59.2	128 21 59	105	Assume ingress at 20 48 23 instead of 20 47 23, which gives the position 20^h 50^m 28^s.2, 38° 33′ 54″	28906	7½	20 50 27.1	38 33 55

Catalogue-position. No.	R.A.	N.P.D.	C.A.		Arg. Gen. Catal. for Equinox 17[illegible] No.	Mag	α	δ
	h m s	° ′ ″	page					
8696	20 53 7.3	164 10 39	19	Assume ingress at 20 49 1 instead of 20 50 1, which gives the position 20^h 52^m 38^s.7, 74 1′ 51″	29091	7$\frac{3}{4}$	20 52 57.8	74 2 8
8703	20 54 19.6	170 53 19	7	Assume ingress at 20 48 55 instead of 20 49 55, which gives the position 20^h 53^m 48^s.7, 80 57′ 45″	29234	7$\frac{1}{4}$	20 53 50.5	80 57 55
8705	20 54 39.0	150 37 51	7	Assume ingress at 20 52 6 instead of 20 51 31, which gives the position 20^h 54^m 56^s.3, 60 12′ 12″	29066	7$\frac{1}{2}$	20 54 55.5	60 42 50
M 8716	20 56 14.0	113 23 58	137	Assume ingress at 20 55 6 instead of 20 55 26, which gives the position 20^h 56^m 3^s.7, 23 28′ 32″	29036	7$\frac{1}{4}$	20 56 3.4	23 28 57
8746	21 1 9.5	163 50 39	19	I can only explain this by assuming ingress at 20 55 22 instead of 20 56 52, and egress at 21 4 52 instead of 21 5 2. Then we should have the position 21^h 0^m 21^s.4, 73 38′ 29″	29255	7$\frac{1}{2}$	21 0 23.2	73 38 1
8775	21 4 43.5	146 56 28	53	Assume egress at 21 9 31 instead of 21 10 31, which gives the position 21^h 4^m 14^s.2, 56 48′ 39″	29269	7$\frac{1}{4}$	21 4 14.1	56 49 25
8781	21 5 50.1	146 41 56	53	Assume egress at 21 9 41 instead of 21 10 41, which gives the position 21^h 5^m 20^s.7, 56 33′ 59″	29284	7$\frac{1}{4}$	21 5 21.7	56 35 0
8816	21 12 22.8	147 29 52	53	Assume ingress at 21 8 37 instead of 21 9 42, which gives the position 21^h 11^m 51^s.0, 57 20′ 50″	29408	8$\frac{1}{4}$	21 11 49.0	57 20 54
8817 8818	21 12 31.0 21 12 31.1	168 27 59 168 27 48	11	There is but one star here. Although two are recorded as observed, 1751 Sept. 21, and two are given in the catalogue appended to the *Coelum Australe*, this is evidently due to some confusion in the record. See *Uranom. Argent.* p. 80. *τ Octantis.*	29533	3$\frac{3}{4}$	21 12 31.4	78 28 35
M 8875	21 25 36.7	115 34 6	137	Both ingress and egress should be diminished by 1^m.	29631	7$\frac{1}{4}$	21 24 35.8	25 33 36
8936	21 36 15.9	161 41 31	23	Assume ingress at 21 27 1 instead of 21 32 1, which gives the position 21^h 33^m 47^s.7, 71 16′ 28″	29905	6$\frac{3}{4}$	21 33 47.2	71 16 17
8989	21 46 3.7	119 29 50	125	Assume egress at 21 49 39 instead of 21 48 59, which gives the position 21^h 46^m 23^s.1, 29 38′ 25″. *η Piscis Austrini.*	30101	5$\frac{3}{4}$	21 46 24.7	29 38 23
A 9003	21 48 18.0	118 35 53	125	Assume ingress at 21 47 57 instead of 21 47 47, which gives the position 21^h 48^m 22^s.7, 28 33′ 11″	30145	7$\frac{1}{2}$	21 48 21.9	28 33 50
A 9004	21 48 50.2	121 5 1	119	Assume ingress at 21 48 51 instead of 21 48 56, which gives the position 21^h 48^m 47^s.6, 31 6′ 9″	30153	7$\frac{1}{4}$	21 48 46.6	31 5 51
9019	21 51 42.3	120 57 16	124	Assume ingress at 21 51 57 instead of 21 51 32, and egress at 21 53 17 instead of 21 52 17, and we obtain the position 21^h 52^m 25^s.0, 30 49′ 41″	30230	8	21 52 27.0	30 49 21
A 9072 A 9086	22 0 55.0 22 2 53.5	115 18 46 111 17 37	137	Interchanging the egresses of these stars, we obtain the positions 22^h 0^m 45^s.9, 25 11′ 27″ 22 3 2^s.8, 21 22 0	30390 30421	7 6$\frac{1}{4}$	22 0 46.2 22 3 3.0	25 15 50 21 22 21
A 9083	22 2 35.8	118 37 14	125	Wrongly reduced in British edition. The place should be given as 22^h 3^m 5^s.8, 28 37′ 13″	30429	7	22 3 7.0	28 37 23
A 9131	22 12 8.0	119 14 35	125	Assume ingress at 22 10 1 not 22 10 9 which gives the position 22^h 12^m 3^s.9, 29 16′ 19″	30608	7	22 12 1.5	29 16 18
A 9162	22 17 17.6	123 34 52	119	Assume egress as 22 18 10 instead of 22 18 19, which gives the position 22^h 17^m 12^s.9, 35 36′ 46″ *β Piscis Austrini.*	30701	4$\frac{1}{4}$	22 17 13.6	[illegible] 27 6
9193	22 24 13.7	112 1 32	65	Assume ingress at 22 22 9 instead of 22 22 29, which gives the position 22^h 24^m 4^s.1, 51 58′ 21″	30857	7$\frac{1}{4}$	22 24 3.9	51 58 18
A 9222	22 29 25.5	120 13 19	124	Assume egress at 22 29 10 instead of 22 31 40, which gives the position 22^h 28^m 24^s.7, 30 39′ 21″	30917	6$\frac{1}{2}$	22 28 21.4	30 39 52
9228	22 30 44.0	171 7 48	7	Assume ingress at 22 25 40 instead of 22 21 40, which gives the position 22^h 31^m 15^s.1, 81 5′ 29″	31096	8	22 31 25.5	81 2 6
9232	22 31 4.6	162 12 12	19	I cannot explain this observation except by supposing the ingress to have been recorded 1^m 15^s, and the egress 1^m too late. These assumptions give the position 22^h 29^m 56^s.6, 72 11′ 28″	31003	7$\frac{1}{4}$	22 29 57.7	72 11 27
9242	22 32 43.3	132 56 38	93	Assuming ingress at 22 29 10 instead of 22 29 30, we obtain the position 22^h 32^m 32^s.5, 43 0 12	31012	7$\frac{1}{4}$	22 32 36.4	43 0 1
9247	22 33 11.7	162 34 18	19	Assume ingress at 22 30 10 instead of 22 31 20, which gives the position 22^h 32^m 25^s.4, 72 11′ 27″	31061	7$\frac{1}{4}$	22 32 35.0	72 11 13

Catalogue-position.			C. A.		Arg. Gen. Catal. for Equinox 1750.0			
No.	R.A.	N.P.D.			No.	Mag	α	δ
	h m s	° ′ ″	page				h m s	° ′ ″
9272	22 36 1.7	154 12 33	35	Assume ingress at 22 34 25 instead of 22 33 45, which gives the position $22^h 36^m 25^s.0$, 64 8′ 16″	31111	7½	22 36 26.4	64 8 3
9278	22 37 0 0	139 1 29	71	Interchanging the egresses of these two stars, we obtain the positions $22^h 37^m 33^s.8$, 48 53′ 19″ 22 37 40 .5, 49 18 25	31113	7¾	22 37 29.9	48 53 36
9285	22 38 14.3	139 7 21			31115	7½	22 37 36.7	49 18 39
9286	22 38 11.3	130 46 21	99	To reconcile this observation with the sky, the ingress must be supposed 35^s earlier, and the egress 30^s later, and furthermore the observation to have been in the lower part. Then the position will be $22^h 38^m 8^s.3$, 40° 37′ 11″	31120	7¾	22 38 8.2	40 37 10
A 9290	22 38 18.2	120 28 9	124	Assume ingress at 22 37 39 instead of 22 37 29, which gives the position $22^h 38^m 53^s.1$, 30° 30′ 19″	31125	8	22 38 53.0	30 30 5
9303	22 41 59.6	134 3 33	93	Assume ingress at 22 38 51 instead of 22 39 51, which gives the position $22^h 41^m 31^s.7$, 43 52′ 35″	31176	8	22 41 31.8	43 52 12
A 9373	22 53 25.1	121 21 11	119	Assume ingress at 22 52 44 instead of 22 52 54, which gives the position $22^h 53^m 19^s.9$, 31 23′ 19″	31392	6¾	22 53 18.3	31 23 36
9371	22 53 37.1	159 15 59	29	Assume ingress at 22 51 52 instead of 22 52 22, which gives the position $22^h 53^m 22^s.7$, 69° 13′ 17″	31418	6½	22 53 22.7	69 13 20
9387	22 56 13.7	134 17 55	85	Assume ingress at 22 56 24 instead of 22 57 24; which gives the position $22^h 56^m 15^s.0$, 44° 7′ 2″	31419	7½	22 56 13.7	44 6 13
9392	22 57 46.3	171 39 42	7	The simplest way of explaining this observation is by assuming the ingress at 22 45 50 instead of 22 47 50, which gives the position $22^h 56^m 48^s$, 81° 47′ 13″	31522	7½	22 57 1.	81 46 54
9397	22 58 11.5	140 54 48	65	Assume egress at 23 2 50 instead of 23 2 25, which gives the position $22^h 58^m 53^s.5$, 50° 38′ 39″	31490	6¾	22 58 53.1	50 58 21
9398	22 58 59.3	140 35 40	65	Assume ingress at 22 59 15 instead of 22 58 40, which gives the position $22^h 59^m 17^s.5$, 50° 30′ 8″	31502	7¾	22 59 17.2	50 29 54
9404	23 0 20.5	140 16 42	65	I cannot reconcile this observation with the sky, except by scarcely permissible assumptions. Yet if the ingress were assumed as 5^s earlier than recorded, and the egress 25^s later, we should have the position $23^h 0^m 30^s.0$, 50° 21′ 28″	31514	8	23 0 30.4	50 21 9
9409	23 1 31.6	143 13 37	59	There seems to be no discoverable error in LACAILLE's record.	31537	7¼	23 1 40.0	53 13 48
9415	23 2 28.3	132 0 14	85	Although the observations of nos. 9415 and 9416 are recorded on the same evening, there appears to be but one star here. The case is analogous to that of *r Octantis*, nos. 8817, 8818.	31546	8¼	23 2 24.8	42 1 18
9416	23 2 30.7	132 0 47						
A 9439	23 5 35.5	119 40 38	125	Reducing the observation for the lower part, we obtain the position $23^h 5^m 36^s.3$, 29° 44′ 34″	31598	6¾	23 5 36.7	29 45 3
9451	23 8 21.2	134 44 15	85	Wrongly reduced in British edition. The place should be given as $23^h 8^m 24^s.2$, 44° 33′ 33″	31654	7¾	23 8 23.8	44 33 14
9506	23 18 1.1	147 41 6	53	Assume ingress at 23 15 40 instead of 23 16 0, which gives the position $23^h 17^m 51^s.2$, 57° 38′ 23″	31831	8¾	23 17 51.3	57 38 46
9541	23 25 5.5	136 53 18	77	Assume ingress at 23 26 45 instead of 23 26 10, which gives the position $23^h 25^m 22^s.0$, 46° 59′ 23″	31975	8	23 25 21.4	46 59 36
9542	23 25 21.3	132 54 3	85	Assume ingress at 23 24 39 instead of 23 24 24, which gives the position $23^h 25^m 29^s.1$, 42 51′ 22″	31976	7½	23 25 30.4	42 51 26
9553	23 27 33.5	133 8 43	85	Assume ingress at 23 26 57 instead of 23 25 57, which gives the position $23^h 28^m 4^s.7$, 42° 58′ 1″	32015	7½	23 28 6.0	42 57 52
9564	23 29 35.0	133 8 12	85	Assume ingress at 23 28 50 instead of 23 28 0, which gives the position $23^h 30^m 1^s.1$, 42° 59′ 16″	32054	8	23 30 4.2	42 59 31
9575	23 30 42.3	129 19 53	95	Assume egress at 23 35 7, instead of 23 33 7, which gives the position $23^h 31^m 39^s.9$, 39° 42′ 54″	32085	7½	23 31 38.7	39 43 8
9712	23 52 5.3	143 35 50	59	Assume ingress at 23 50 47 instead of 23 50 22, which gives the position $23^h 52^m 18^s.2$, 53° 32′ 12″	32428	7½	23 52 18.5	53 32 23
9734	23 55 6.8	169 54 28	11	Assume ingress at 23 51 40 instead of 23 51 0, which gives the position $23^h 55^m 25^s.7$, 79° 58′ 11″	35	7¼	23 55 26.1	79 59 29
9743	23 56 37.5	165 29 58	15	Assume ingress at 23 52 14 instead of 23 53 14, which gives the position $23^h 56^m 6^s.8$, 75° 37′ 21″	45	8	23 56 3.8	75 37 49

Catalogue-position.			C. A.		Arg. Gen. Catal. [illegible]			
No.	R.A.	N.P.D.			No.	Mag	α	δ
	h m s	° ′ ″	page					
1592	4 37 15.1	175 49 33	1	This observation is clearly incorrect, as recorded. The ingress should probably be some minutes earlier, but even this supposition is inadequate to explain the observations.	4672	6½	4 35 1.4	85 55 [illegible]
4011	9 35 51.3	134 49 55	79	Assume ingress at 9 36 52 instead of 9 36 32, which gives the position 9h 36m 1s.5, 44° 46′ 23″	13308	7¾	9 36 4.0	44 46 5
4014	9 36 23.2	134 50 16	79	Assume ingress at 9 37 23 instead of 9 37 3, which gives the position 9h 36m 53s.5, 44° 46′ 44″	13323	7	9 36 33.6	41 46 21
5882	11 3 41.0	175 27 44	5	Assuming the ingress as 1s earlier, and the egress as 1s later than recorded, we obtain the position 14h 3m 49s.2, 85° 22′ 19″	19809	7¼	14 3 59.7	85 22 24

EPHEMERIS OF VARIABLES OF THE *ALGOL*-TYPE.

Approximate Greenwich M.T., 1890.

	June			July			August			September			September	
	d	h		d	h		d	h		d	h		d	h
δ Librae	1	12	*U* Ophiuchi	1	11	*U* Ophiuchi	1	12	Algol	1	6	*U* Cephei	23	15
U Coronae	2	7	*Y* Cygni	2	16	*Y* Cygni	1	15	*U* Ophiuchi	1	12	*Y* Cygni	24	13
Y Cygni	2	17	*U* Coronae	3	9	*U* Coronae	3	11	λ Tauri	1	14	*R* Can. Maj.	24	14
U Cephei	3	11	*U* Cephei	3	9	Algol	3	14	*U* Ophiuchi	2	8	*R* Can. Maj.	25	18
U Ophiuchi	3	18	*U* Ophiuchi	4	19	*Y* Cygni	4	15	δ Librae	2	11	*U* Ophiuchi	27	12
U Ophiuchi	4	15	*U* Ophiuchi	5	15	*U* Cephei	4	19	*U* Coronae	3	12	*Y* Cygni	27	13
U Ophiuchi	5	11	*Y* Cygni	5	16	δ Librae	5	16	*Y* Cygni	3	14	*U* Coronae	27	16
Y Cygni	5	17	Algol	5	22	Algol	6	11	*U* Cephei	3	17	*U* Ophiuchi	28	8
δ Librae	8	11	δ Librae	6	10	*U* Ophiuchi	6	12	λ Tauri	5	13	*U* Cephei	28	15
U Cephei	8	11	*U* Ophiuchi	6	11	*Y* Cygni	7	15	*U* Ophiuchi	6	13	δ Librae	30	12
Y Cygni	8	17	*U* Cephei	8	8	*U* Cephei	9	18	*Y* Cygni	6	13	*Y* Cygni	30	13
U Ophiuchi	8	19	*Y* Cygni	8	16	*U* Coronae	10	8	*U* Ophiuchi	7	9			
S Cancri	9	13	Algol	8	19	*Y* Cygni	10	14	*R* Can. Maj.	7	13		October	
U Ophiuchi	9	16	*U* Ophiuchi	10	16	*U* Ophiuchi	11	13	*U* Cephei	8	16	*S* Cancri	1	8
U Ophiuchi	10	12	*U* Ophiuchi	11	12	*U* Ophiuchi	12	9	*R* Can. Maj.	8	17	*U* Ophiuchi	2	13
Y Cygni	11	17	*Y* Cygni	11	15	δ Librae	12	15	*Y* Cygni	9	13	Algol	2	19
U Coronae	12	16	Algol	11	16	λ Tauri	12	20	δ Librae	9	14	*U* Ophiuchi	3	9
U Cephei	13	10	*U* Ophiuchi	12	8	*Y* Cygni	13	14	Algol	9	20	*Y* Cygni	3	13
U Ophiuchi	14	16	*U* Cephei	13	8	*U* Coronae	13	19	*R* Can. Maj.	9	20	*U* Cephei	3	14
Y Cygni	14	16	δ Librae	13	9	*U* Cephei	14	18	*U* Coronae	10	10	*R* Can. Maj.	3	17
δ Librae	15	11	U Coronae	13	18	*Y* Cygni	16	14	*U* Ophiuchi	11	14	*U* Coronae	4	14
U Ophiuchi	15	12	*Y* Cygni	14	15	λ Tauri	16	19	*S* Cancri	12	9	*R* Can. Maj.	4	20
U Ophiuchi	16	9	*U* Ophiuchi	16	13	*U* Ophiuchi	17	10	*U* Ophiuchi	12	10	Algol	5	16
Y Cygni	17	16	*U* Ophiuchi	17	9	*Y* Cygni	19	14	*Y* Cygni	12	13	*Y* Cygni	6	13
U Cephei	18	10	*Y* Cygni	17	15	δ Librae	19	15	Algol	12	17	*U* Ophiuchi	7	14
S Cancri	19	0	*U* Cephei	18	8	*U* Cephei	19	18	*U* Cephei	13	16	*U* Ophiuchi	8	10
U Coronae	19	14	δ Librae	20	9	*U* Coronae	20	17	*R* Can. Maj.	15	12	Algol	8	12
U Ophiuchi	19	17	*U* Coronae	20	15	λ Tauri	20	17	*Y* Cygni	15	13	*U* Cephei	8	14
U Ophiuchi	20	13	*Y* Cygni	20	15	Algol	20	19	Algol	15	14	*U* Ophiuchi	9	6
Y Cygni	20	16	*U* Ophiuchi	21	14	*U* Ophiuchi	22	11	δ Librae	16	13	*Y* Cygni	9	13
U Ophiuchi	21	9	*U* Ophiuchi	22	10	*Y* Cygni	22	14	*R* Can. Maj.	16	16	*S* Cancri	10	20
δ Librae	22	10	*U* Cephei	23	7	Algol	23	16	*U* Coronae	17	8	Algol	11	10
U Cephei	23	9	*Y* Cygni	23	15	λ Tauri	24	16	*U* Ophiuchi	17	11	*U* Coronae	11	12
Y Cygni	23	16	*U* Ophiuchi	26	14	*U* Cephei	24	17	*R* Can. Maj.	17	19	*R* Can. Maj.	11	15
U Ophiuchi	24	18	*Y* Cygni	26	15	*Y* Cygni	25	14	Algol	18	11	*Y* Cygni	12	13
U Ophiuchi	25	14	δ Librae	27	8	Algol	26	13	*Y* Cygni	18	13	*R* Can. Maj.	12	19
U Ophiuchi	26	10	*U* Ophiuchi	27	11	δ Librae	26	14	*U* Cephei	18	16	*U* Ophiuchi	13	11
U Coronae	26	11	*U* Coronae	27	13	*U* Ophiuchi	27	11	*U* Coronae	20	19	*U* Cephei	13	13
Y Cygni	26	16	*U* Cephei	28	7	*U* Coronae	27	15	Algol	21	8	Algol	14	6
U Cephei	28	9	*U* Ophiuchi	28	7	*Y* Cygni	28	14	*Y* Cygni	21	13	*U* Ophiuchi	14	7
δ Librae	29	10	Algol	28	20	λ Tauri	28	15	*S* Cancri	21	21	*Y* Cygni	15	12
Y Cygni	29	16	*Y* Cygni	29	15	Algol	29	9	*U* Ophiuchi	22	12	*U* Coronae	18	10
U Ophiuchi	29	18	Algol	31	17	*U* Cephei	29	17	*U* Ophiuchi	23	8	*Y* Cygni	18	12
U Ophiuchi	30	15				*Y* Cygni	31	14	δ Librae	23	13	*U* Cephei	18	13

OBSERVATIONS OF COMET *a* 1890,

MADE AT THE U. S. NAVAL OBSERVATORY WITH THE 9.6-INCH EQUATORIAL.

BY PROF. E. FRISBY.

1890 Washington M.T.	*	No. Comp.	☄ — * $\Delta\alpha$	☄ — * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
d h m s			m s	′ ″	h m s	° ′ ″		
May 12 11 38 59.8	1	10 , 2	+2 33.01	—9 37.0	20 42 7.20	+39 49 55.0	*n*9.775	0.586
15 11 21 51.2	2	14 , 3	+1 29.32	+4 51.3	20 35 0.77	+42 41 4.3	*n*9.791	0.550

Mean Places for 1890.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	20 39 33.57	+0.62	+39 59 48.6	—16.6	Paris 1880
2	20 33 30.87	+0.58	+42 36 26.6	—16.6	Radcliffe 4891

SPECTROGRAPHIC OBSERVATIONS OF *SPICA*.

At the full session of the Berlin Academy of Sciences, on April 24, Dr. AUWERS communicated results of the spectrographic impressions of the star *a Virginis* made at the Potsdam astrophysical observatory, from which Prof. VOGEL had deduced an orbital motion of short period, for this star.

The spectrum belongs to the class I *a*, and shows broad diffuse hydrogen-lines. Two photographic impressions of it, in April 1889, agreed in exhibiting an unusually strong displacement of the lines toward the violet, while a third taken only two days after the second gave a considerable displacement toward the red. To obtain an explanation of this, photographs of *Spica* were made at every favorable opportunity during the month of April. From these the following values have been deduced for the motion of the star; the positive sign denoting motion in the direction from the sun, and the negative sign, motion toward it.

Potsdam M.T.		h	m	Obs'd Motion	Red. to ⊙	*—⊙
1889 April	21	9	15	— 85.8 kilom.	—5.2 kilom.	— 91.0 kilom.
	29	11	10	— 88.8	—8.9	— 97.7
May	1	10	58	+ 55.5	—9.6	+ 45.9
1890 April	4	11	30	— 25.2	+3.7	— 21.5
	9	10	30	—105.1	+1.5	—103.6
	10	11	30	— 2.2	+0.7	— 1.5
	11	10	50	+ 56.2	0.0	+ 56.2
	13	10	50	—108.8	—0.7	—109.5
	15	11	0	+ 83.6	—2.2	+ 81.4

These observations are represented satisfactorily, for a first approximation, by the formula

$$v = v_0 \sin\left(\frac{t-t_0}{p} \,.\, 360^\circ\right),$$

if we assume 1890 April 2 10ʰ Potsdam M.T. for the epoch, $p = 4^d\ 0^h.3$ for the period, and for the greatest velocity in the line of vision $v_0 = 89$ kilometers. If we furthermore free the observations from the effect of a movement of translation, provisionally assumed as —22 *km*, we have the following residuals, (O—C):

	km		km		km
1889 Apr. 21	+20.0	1890 Apr. 4	+ 8.9	1890 Apr. 11	—10.4
29	+13.3	9	+ 7.4	13	+ 1.5
May 1	—20.7	10	+15.5	15	+14.8

The period is assumed from a comparison of last year's observations with those of this year, and the number of periods in a year appears not to be uncertain by more than ±2 periods.

In case the plane of the orbit is not greatly inclined to the line of vision, and the velocity of 89 *km* can therefore be approximately regarded as the orbital velocity, the distance of the observed star from the center of the system would amount to about 4 880 000 *km*. Should the companion be at an equal distance from the center of gravity, it would result that the mass of each of the two bodies would be 1.2 that of the sun. For a parallax of 0″.2 the maximum apparent distance between the two components would only amount to 0″.013, so that the companion could not be visible even with the most powerful instruments. It is not perceptible upon the Potsdam plates; but from this can only be inferred that its brightness does not surpass the third magnitude.

Prof. VOGEL adds that numerous observations of *Rigel* made at Potsdam also indicate a periodic motion as probable; but that the amount of this variation is small, and not capable of safe determination from the materials at hand.

CORRIGENDA.

No. 218, p. 9, col. 2, line 4 from below, erase x, which was intended for the sign of multiplication.
p. 10, col. 1, line 7 from below, for $\sec f'$ put $\sqrt{\sec 2f'}$.
col. 1, line 18 from below, for $\sqrt{\cos 2f}$, put $\sqrt{\cos 2f'}$.

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SPECTROGRAPHIC OBSERVATIONS OF SPICA.
CORRIGENDA.

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ON THE SECULAR AND LONG-PERIOD INEQUALITIES IN THE MOON'S MOTION,

BY JOHN N. STOCKWELL.

1. During the summer of 1889 I busied myself with the problem of the secular variation of the motion of the moon's perigee and node. Although I had previously examined with much care the secular variation of the moon's mean longitude, I had never yet given any attention to the similar inequalities which affect the motion of these two elements. It will be remembered, by those conversant with the subject, that the mean motions of the perigee and node were supposed to be always the same, until LAPLACE showed that they were subjected to secular inequalities similar to those of the mean longitude, and arising from the same cause. The amount of each of these secular inequalities has a constant ratio to that of the mean motion; and hence they may easily be found from that of the mean longitude when these ratios have once been determined. The value which I have found for the secular variation of the mean longitude of the moon's node does not differ very materially from that found by LAPLACE and subsequent investigators; and this small difference is not of much importance in this investigation. But it is otherwise with the secular equation of the motion of the moon's perigee. If the value which I have obtained for the secular motion of the moon's perigee is nearly correct, the value found by LAPLACE and his immediate successors cannot be regarded even as a first approximation to the value of that motion. But in order that the reader may judge of the importance of this investigation I will first give the values found by LAPLACE and others for the coefficient of the square of the time in the expression of the mean longitude of the perigee.

2. If we denote the mean longitude of the moon's perigee by ω, and also let i denote the number of centuries from a given epoch, we shall have for the variation, $\delta\omega$, of the mean longitude of the perigee at any number of centuries from the epoch: —

according to LAPLACE, $\delta\omega = -30''.55 \cdot i^2$
according to BÖRG and BURCKHARDT, $\delta\omega = -29.98 \cdot i^2$
according to DAMOISEAU, $\delta\omega = -39.70 \cdot i^2$
according to PLANA, $\delta\omega = -40.23 \cdot i^2$
while HANSEN first gives $\delta\omega = -39.18 \cdot i^2$
and afterwards reduces it to $\delta\omega = -36.31 \cdot i^2$

These values are taken from AIRY'S *Memoir* on the eclipses of AGATHOCLES, THALES and XERXES, which is published in the *Philosophical Transactions of the Royal Society of London* for the year 1853.

If any question of science can be definitely established by the common consent of investigators, there would seem to be small reason to doubt the general accuracy of the preceding coefficients. And yet I have found, by direct calculation, that $\delta\omega$ is very nearly expressed by the equation

$$\delta\omega = +15''.61 \cdot i^2$$

And since the motion of the perigee is direct, it follows that this motion is *accelerated* instead of being *retarded*, from age to age, as has been hitherto supposed.

3. I shall now give an abstract of the calculation by which this last value of $\delta\omega$ has been obtained. For this purpose, we shall observe that if we neglect the inclination of the moon's orbit to the ecliptic, the general differential equation of the motion of the perigee will be

$$\mu e \frac{d\omega}{dt} = r^2 \cos(v-\omega)\frac{dv}{dt}\cdot\left(\frac{dR}{dr}\right) + \left\{\cos(v-\omega)\frac{dr}{dt} - 2r\sin(v-\omega)\frac{dv}{dt}\right\}\left(\frac{dR}{dv}\right) \tag{1}$$

in which μ denotes the sum of the masses of the earth and moon, e the eccentricity of the moon's orbit, and R, the disturbing function. If we now put, for brevity,

$$\left\{\begin{aligned} [0] &= r^2\cos(v-\omega)\frac{dv}{dt} \qquad \text{and} \\ [1] &= \cos(v-\omega)\frac{dv}{dt} - 2r\sin(r-\omega)\frac{dr}{dt} \end{aligned}\right. \tag{2}$$

The above equation will be simplified, and we shall have

$$\mu e\frac{d\omega}{dt} = [0]\left(\frac{dR}{dr}\right) + [1]\left(\frac{dR}{dv}\right) \tag{3}$$

This equation will give the complete value of $\frac{d\omega}{dt}$, arising from the first power of the disturbing force. If we represent the increments of $[0]$, $[1]$, $\left(\frac{dR}{dr}\right)$, &c., arising from the first and second powers of the disturbing force, by

$$\delta[0],\ \delta\left(\frac{dR}{dr}\right),\ \delta^2[0],\ \text{\&c.},$$

the corresponding increments to the motion of the perigee will be given by the equations

$$\mu e\delta\frac{d\omega}{dt}=[0]\,\delta\left(\frac{dR}{dr}\right)+\left(\frac{dR}{dr}\right)\delta[0]+[1]\,\delta\left(\frac{dR}{dv}\right)+\left(\frac{dR}{dv}\right)\delta[1]\,; \tag{4}$$

$$\mu e\delta^2\frac{d\omega}{dt}=[0]\,\delta^2\left(\frac{dR}{dr}\right)+2\delta[0]\,\delta\left(\frac{dR}{dr}\right)+\left(\frac{dR}{dr}\right)\delta^2[0]+[1]\,\delta^2\left(\frac{dR}{dv}\right)+2\delta[1]\,\delta\left(\frac{dR}{dv}\right)+\left(\frac{dR}{dv}\right)\delta^2[1] \tag{5}$$

Equations (3–5) will give the value of $\frac{d\omega}{dt}$ correct to terms depending on the cube of the disturbing force. We shall now attend to the development of these equations.

4. For this purpose we must first substitute the values of r and v, corresponding to the elliptical motion; and we may neglect all the terms depending on the square, and higher powers of e, but must retain the terms depending the first and second powers of e'. The full development of these various quantities would occupy too much space to be given here: and I shall therefore give only the quantities actually required. Denoting by nt and $n't$, the mean longitudes of the moon and sun; and by m^2 the coefficient of the disturbing function, we shall have the following equations to be used in the computation of equations (3–5) on which the motion of the perigee depends.

$$[0]=a^2n\{-e+\cos(nt-\omega)+e\cos 2(nt-\omega)\} \tag{6}$$

$$[1]=2an\{-\sin(nt-\omega)-\tfrac{5}{4}e\sin 2(nt-\omega)\} \tag{7}$$

$$\left\{\begin{aligned}\delta[0]=\ &2an\{-\tfrac{1}{2}e+\cos(nt-\omega)+\tfrac{3}{2}e\cos 2(nt-\omega)\}\delta r\\&+a^2n\left\{-\sin(nt-\omega)-e\sin 2(nt-\omega)\right\}\delta v+a^2\left\{-2e+\cos(nt-\omega)\right\}\frac{d\delta v}{dt}\end{aligned}\right. \tag{8}$$

$$\left\{\begin{aligned}\delta[1]=\ &2n\{-\sin(nt-\omega)-2e\sin 2(nt-\omega)\}\delta r+an\{\tfrac{1}{2}e-2\cos(nt-\omega)-\tfrac{5}{2}e\cos 2(nt-\omega)\}\delta v\\&+\left\{-e+\cos(nt-\omega)+e\cos 2(nt-\omega)\right\}\frac{d\delta r}{dt}+a\left\{-2\sin(nt-\omega)-e\sin 2(nt-\omega)\right\}\frac{d\delta v}{dt}\end{aligned}\right. \tag{9}$$

$$\left\{\begin{aligned}\delta^2[0]=\ &2an\{-\tfrac{1}{2}e+\cos(nt-\omega)+\tfrac{3}{2}e\cos 2(nt-\omega)\}\delta^2r+a^2n\{-\sin(nt-\omega)-e\sin 2(nt-\omega)\}\delta^2v\\&+a^2\left\{-2e+\cos(nt-\omega)\right\}\frac{d\delta^2v}{dt}+n\left\{\cos(nt-\omega)+2e\cos 2(nt-\omega)\right\}\delta r^2\\&+a^2n\{\tfrac{1}{2}e-\tfrac{1}{2}\cos(nt-\omega)-\tfrac{1}{2}e\cos 2(nt-\omega)\}\delta v^2+an\{-2\sin(nt-\omega)-3e\sin 2(nt-\omega)\}\delta r\delta v\\&+a\left\{-3e+2\cos(nt-\omega)+e\cos 2(nt-\omega)\right\}\frac{d\delta v}{dt}\delta r-a^2\sin(nt-\omega)\frac{d\delta v}{dt}\delta v\end{aligned}\right. \tag{10}$$

$$\left\{\begin{aligned}\delta^2[1]=\ &2n\{-\sin(nt-\omega)-2e\sin 2(nt-\omega)\}\delta^2r+an\{\tfrac{1}{2}e-2\cos(nt-\omega)-\tfrac{5}{2}e\cos 2(nt-\omega)\}\delta^2v\\&+\left\{-e+\cos(nt-\omega)+e\cos 2(nt-\omega)\right\}\frac{d\delta^2r}{dt}+a\left\{-2\sin(nt-\omega)-e\sin 2(nt-\omega)\right\}\frac{d\delta^2v}{dt}\\&+an\{\sin(nt-\omega)+\tfrac{5}{4}e\sin 2(nt-\omega)\}\delta v^2+n\{-2\cos(nt-\omega)-4e\cos 2(nt-\omega)\}\delta r\delta v\\&+\left\{-2\sin(nt-\omega)-2e\sin 2(nt-\omega)\right\}\frac{d\delta v}{dt}\delta r-\left\{\sin(nt-\omega)+e\sin 2(nt-\omega)\right\}\frac{d\delta r}{dt}\delta v\\&+a\left\{3e-2\cos(nt-\omega)-e\cos 2(nt-\omega)\right\}\frac{d\delta v}{dt}\delta v\end{aligned}\right. \tag{11}$$

$$\left\{\begin{aligned}\left(\frac{dR}{dr}\right)=\frac{\bar{m}^2}{a^2}\Big\{&-\tfrac{1}{2}\{1+\tfrac{3}{2}e'^2\}+\tfrac{1}{2}e\{1+\tfrac{3}{2}e'^2\}\cos(nt-\omega)-\tfrac{3}{2}\{1-\tfrac{5}{2}e'^2\}\cos 2(nt-n't)\\&-\tfrac{9}{4}e\{1-\tfrac{5}{2}e'^2\}\cos(3nt-2n't-\omega)+\tfrac{15}{4}e\{1-\tfrac{5}{2}e'^2\}\cos(nt-2n't+\omega)\Big\}\end{aligned}\right. \tag{12}$$

$$\left\{\begin{aligned}\left(\frac{dR}{dv}\right)=\frac{\bar{m}^2}{a}\Big\{&\tfrac{3}{2}\{1-\tfrac{5}{2}e'^2\}\sin 2(nt-n't)+\tfrac{3}{2}e\{1-\tfrac{5}{2}e'^2\}\sin(3nt-2n't-\omega)\\&-\tfrac{9}{2}e\{1-\tfrac{5}{2}e'^2\}\sin(nt-2n't+\omega)\Big\}\end{aligned}\right. \tag{13}$$

$$\left\{\begin{aligned}\delta\left(\frac{dR}{dr}\right)=\frac{\bar{m}^2}{a^3}\Big\{&-\tfrac{1}{2}\{1+\tfrac{3}{2}e'^2\}-\tfrac{3}{2}\{1-\tfrac{5}{2}e'^2\}\cos 2(nt-n't)-3e\{1-\tfrac{5}{2}e'^2\}\cos(3nt-2n't-\omega)\\&+3e\{1-\tfrac{5}{2}e'^2\}\cos(nt-2n't+\omega)-\tfrac{3}{2}e'\cos(n't-\omega')\Big\}\delta r\\+\frac{\bar{m}^2}{a^2}\Big\{&3\{1-\tfrac{5}{2}e'^2\}\sin 2(nt-n't)+\tfrac{9}{2}e\{1-\tfrac{5}{2}e'^2\}\sin(3nt-2n't-\omega)\\&-\tfrac{15}{2}e\{1-\tfrac{5}{2}e'^2\}\sin(nt-2n't+\omega)\Big\}\delta v\end{aligned}\right. \tag{14}$$

$$\begin{aligned}\delta\left(\frac{dR}{dv}\right) = \frac{m^2}{a^2}\Big\{ & 3\{1-\tfrac{5}{2}e'^2\}\sin 2(nt-n't) + \tfrac{9}{2}e\{1-\tfrac{5}{2}e'^2\}\sin(3nt-2n't-\omega) \\ & -\tfrac{15}{2}e\{1-\tfrac{5}{2}e'^2\}\sin(nt-2n't+\omega)\Big\}\delta r \\ + \frac{\overline{m}^2}{a}\Big\{ & 3\{1-\tfrac{5}{2}e'^2\}\cos 2(nt-n't) + 3e\{1-\tfrac{5}{2}e'^2\}\cos(3nt-2n't-\omega) \\ & -9e\{1-\tfrac{5}{2}e'^2\}\cos(nt-2n't+\omega)\Big\}\delta v\end{aligned} \tag{15}$$

$$\begin{aligned}\delta^2\left(\frac{dR}{dr}\right) = \frac{\overline{m}^2}{a^3}\Big\{ & -\tfrac{1}{2}\{1+\tfrac{3}{2}e'^2\} - \tfrac{3}{2}e'\cos(n't-\omega') - \tfrac{3}{2}\{1-\tfrac{5}{2}e'^2\}\cos 2(nt-n't) \\ & + 3e\{1-\tfrac{5}{2}e'^2\}\{\cos(nt-2n't+\omega) - \cos(3nt-2n't-\omega)\}\Big\}\delta^2 r \\ + 3\frac{\overline{m}^2}{a^2}\Big\{ & 1-\tfrac{5}{2}e'^2\Big\}\Big\{\sin 2(nt-n't) + \tfrac{3}{2}e\sin(3nt-2n't-\omega) - \tfrac{5}{2}e\sin(nt-2n't+\omega)\Big\}\delta^2 v \\ + 3\frac{m^2}{a^2}\Big\{ & 1-\tfrac{5}{2}e'^2\Big\}\Big\{\cos 2(nt-n't) + \tfrac{3}{2}e\cos(3nt-2n't-\omega) - \tfrac{5}{2}e\cos(nt-2n't+\omega)\Big\}\delta v^2 \\ + 3\frac{m^2}{a^3}\Big\{ & 1-\tfrac{5}{2}e'^2\Big\}\Big\{\sin 2(nt-n't) + 2e\sin(3nt-2n't-\omega) - 2e\sin(nt-2n't+\omega)\Big\}\delta r\delta v\end{aligned} \tag{16}$$

$$\begin{aligned}\delta^2\left(\frac{dR}{dv}\right) = 3\frac{m^2}{a^2}\Big\{ & 1-\tfrac{5}{2}e'^2\Big\}\Big\{\sin 2(nt-n't) + \tfrac{3}{2}e\sin(3nt-2n't-\omega) - \tfrac{5}{2}e\sin(nt-2n't+\omega)\Big\}\delta^2 r \\ + 3\frac{m^2}{a}\Big\{ & 1-\tfrac{5}{2}e'^2\Big\}\Big\{\cos 2(nt-n't) + e\cos(3nt-2n't-\omega) - 3e\cos(nt-2n't+\omega)\Big\}\delta^2 v \\ + 3\frac{\overline{m}^2}{a^3}\Big\{ & 1-\tfrac{5}{2}e'^2\Big\}\Big\{\tfrac{1}{2}\sin 2(nt-n't) + e\sin(3nt-2n't-\omega) - e\sin(nt-2n't+\omega)\Big\}\delta r^2 \\ + 3\frac{m^2}{a}\Big\{ & 1-\tfrac{5}{2}e'^2\Big\}\Big\{-\sin 2(nt-n't) - e\sin(3nt-2n't-\omega) + 3e\sin(nt-2n't+\omega)\Big\}\delta v^2 \\ + 3\frac{m^2}{a^2}\Big\{ & 1-\tfrac{5}{2}e'^2\Big\}\Big\{2\cos 2(nt-n't) + 3e\cos(3nt-2n't-\omega) - 5e\cos(nt-2n't+\omega)\Big\}\delta r\delta v\end{aligned} \tag{17}$$

The values of δr, δv, &c., to be used in these equations are given in the author's *Theory of the Moon's Motion*. If we make the necessary substitutions we shall get the following equations.

$$\begin{aligned}\delta[0] = a^2\frac{\overline{m}^2}{\mu}n\Big\{ & \tfrac{25}{24}e\{1+\tfrac{3}{2}e'^2\} - \tfrac{1}{3}\{1+\tfrac{3}{2}e'^2\}\cos(nt-\omega) + ee'(4.525323)\cos(n't-\omega') \\ & - e'(20.16597)\cos(nt+n't-\omega-\omega') + e'(20.16597)\cos(nt-n't-\omega+\omega') \\ & + e(29.20475)\{1-\tfrac{5}{2}e'^2\}\cos 2(nt-n't) + (1.320250)\{1-\tfrac{5}{2}e'^2\}\cos(3nt-2n't-\omega) \\ & - (0.509614)\{1-\tfrac{5}{2}e'^2\}\cos(nt-2n't+\omega) + ee'(2.472383)\cos(2nt-n't-\omega') \\ & - ee'(21.47066)\cos(2nt-3n't+\omega') - e'(0.5887631)\cos(3nt-n't-\omega-\omega') \\ & + e'(0.2000889)\cos(nt-n't+\omega-\omega') + e'(5.231535)\cos(3nt-3n't-\omega+\omega') \\ & - e'(2.271785)\cos(nt-3n't+\omega+\omega')\Big\}\end{aligned} \tag{18}$$

$$\begin{aligned}\delta[1] = a\frac{m^2}{\mu}n\Big\{ & - ee'(20.05314)\sin(n't-\omega') + e'(14.78396)\sin(nt+n't-\omega-\omega') \\ & - e'(38.76708)\sin(nt-n't-\omega+\omega') - e(79.40903)\{1-\tfrac{5}{2}e'^2\}\sin 2(nt-n't) \\ & - (2.736822)\{1-\tfrac{5}{2}e'^2\}\sin(3nt-2n't-\omega) + (1.459792)\{1-\tfrac{5}{2}e'^2\}\sin(nt-2n't+\omega) \\ & + ee'(0.693333)\sin(2nt-n't-\omega') - ee'(5.454580)\sin(2nt-3n't+\omega') \\ & + e'(1.198658)\sin(3nt-n't-\omega-\omega') - e'(0.708714)\sin(nt-n't+\omega-\omega') \\ & - e'(11.04492)\sin(3nt-3n't-\omega+\omega') + e'(5.24002)\sin(nt-3n't+\omega+\omega')\Big\}\end{aligned} \tag{19}$$

$$\begin{aligned}\delta^2[0] = a^2\frac{m^4}{\mu^2}n\Big\{ & - e\{67.4983 - 411.2729e'^2\} - \{3.351302 - 73.3900e'^2\}\cos(nt-\omega) \\ & - ee'(184.0221)\cos(n't-\omega') + e\{176.1078 + 2707.422e'^2\}\cos 2(nt-n't) \\ & - \{0.441485 + 218.3404e'^2\}\cos(3nt-2n't-\omega) + ee'(254.0268)\cos(2nt-n't-\omega') \\ & + \{1.029728 + 86.7700e'^2\}\cos(nt-2n't+\omega) - ee'(248.40037)\cos(2nt-3n't+\omega') \\ & + e'(549.6786)\cos(nt+n't-\omega-\omega') - e'(569.5770)\cos(nt-n't-\omega+\omega') \\ & - e'(45.05580)\cos(3nt-n't-\omega-\omega') - e'(31.07381)\cos(nt-n't+\omega-\omega') \\ & + e'(44.83831)\cos(3nt-3n't-\omega+\omega') + e'(20.88817)\cos(nt-3n't+\omega+\omega')\Big\}\end{aligned} \tag{20}$$

$$
(21)\qquad \left\{\begin{aligned}
\delta^2[1] = a\frac{m^4}{\mu^2}n\Big\{ &-e\{429.7685 + 4998.475\,e'^2\}\sin 2(nt-n't) - ee'(156.03453)\sin(2nt-n't-\omega') \\
&+ \{0.550656 + 453.3317\,e'^2\}\sin(3nt-2n't-\omega) + ee'(144.88721)\sin(2nt-3n't+\omega') \\
&- \{0.883996 + 243.5137\,e'^2\}\sin(nt-2n't+\omega) + e'(93.41512)\sin(3nt-n't-\omega-\omega') \\
&- e'(102.05414)\sin(nt-n't+\omega-\omega') - e'(99.52817)\sin(3nt-3n't-\omega+\omega') \\
&\qquad\qquad + e'(89.44177)\sin(nt-3n't+\omega+\omega')\Big\}
\end{aligned}\right.
$$

$$
(22)\qquad \left\{\begin{aligned}
\delta\left(\frac{dR}{dr}\right) = \frac{\bar{m}^4}{a^2\mu}\Big\{ &+\{3.793882 + 34.3901\,e'^2\} + e\{125.10889 - 628.3882\,e'^2\}\cos(nt-\omega) \\
&+ e'(24.16916)\cos(n't-\omega') + ee'(267.5236)\cos(nt+n't-\omega-\omega') \\
&+ ee'(347.0538)\cos(nt-n't-\omega+\omega') + \{0.893835 + 241.16936\,e'^2\}\cos 2(nt-n't) \\
&+ e(1.612274)\{1-e'^2\}\cos(3nt-2n't-\omega) + e(12.23765)\{1-e'^2\}\cos(nt-2n't+\omega) \\
&+ e'(59.92482)\cos(2nt-n't-\omega') - e'(57.19563)\cos(2nt-3n't+\omega') \\
&+ ee'(164.4105)\cos(3nt-n't-\omega-\omega') - ee'(0.59817)\cos(nt-n't+\omega-\omega') \\
&- ee'(169.88794)\cos(3nt-3n't-\omega+\omega') + ee'(77.39854)\cos(nt-3n't+\omega+\omega')\Big\}
\end{aligned}\right.
$$

$$
(23)\qquad \left\{\begin{aligned}
\delta\left(\frac{dR}{dv}\right) = \frac{\bar{m}^4}{a\mu}\Big\{ &- e(157.4356)\{1-5e'^2\}\sin(nt-\omega) - e'(2.36365)\sin(n't-\omega') \\
&- ee'(360.2211)\sin(nt+n't-\omega-\omega') - ee'(422.2729)\sin(nt-n't-\omega+\omega') \\
&- \{\tfrac{1}{2} + 234.70365\,e'^1\}\sin 2(nt-n't) - e(0.5625)\{1-e'^2\}\sin(3nt-2n't-\omega) \\
&+ e(3.6875)\{1-e'^2\}\sin(nt-2n't+\omega) - e'(57.98525)\sin(2nt-n't-\omega') \\
&+ e'(61.01057)\sin(2nt-3n't+\omega') - ee'(107.02778)\sin(3nt-n't-\omega-\omega') \\
&+ ee'(7.60013)\sin(nt-n't+\omega-\omega') + ee'(118.41973)\sin(3nt-3n't-\omega+\omega') \\
&\qquad\qquad - ee'(22.06616)\sin(nt-3n't+\omega+\omega')\Big\}
\end{aligned}\right.
$$

$$
(24)\qquad \delta^2\left(\frac{dR}{dr}\right) = \frac{m^6}{a^2\mu^2}\Big\{-\{3.538562 + 574.9660\,e'^2\} + e\{588.6978 + 6334.377\,e'^2\}\cos(nt-\omega)\Big\}
$$

$$
(25)\qquad \delta^2\left(\frac{dR}{dv}\right) = \frac{\bar{m}^6}{a\mu^2}\Big\{-e\{657.8323 + 5353.883\,e'^2\}\sin(nt-\omega)\Big\}
$$

5. If we substitute these quantities in equations (3–5) we shall get the following values of the non-periodic terms in the analytical expression for the motion of the moon's perigee.

$$
(26)\qquad \frac{d\omega}{dt} = \frac{\bar{m}^2}{\mu}n\Big\{\tfrac{3}{4}\{1 + \tfrac{3}{2}e'^2\}\Big\}
$$

$$
(27)\qquad \left\{\begin{aligned}
\delta\frac{d\omega}{dt} = \frac{m^4}{\mu^2}n\Big\{ &-\{3.793882 + 34.39014\,e'^2\} + \{62.554445 - 314.1941\,e'^2\} \\
&- \tfrac{25}{48}\{1 + 3e'^2\} - \tfrac{1}{12}\{1 + 3e'^2\} - e'^2(3.393992) - e'^2(7.562238) \\
&+ e'^2(7.562238) - (21.903562)\{1 - 5e'^2\} - (1.485281)\{1 - 5e'^2\} \\
&- (0.955526)\{1 - 5e'^2\} + e'^2(0.927144) + e'^2(56.36048) - e'^2(0.3311793) \\
&- e'^2(0.1875833) - e'^2(20.599169) - e'^2(14.928276) + (157.4356)\{1 - 5e'^2\} \\
&- (59.55677)\{1 - 5e'^2\} - (2.0526165)\{1 - 5e'^2\} - (3.284532)\{1 - 5e'^2\} \\
&- \tfrac{1}{4}e'^2 - e'^2(14.3182725) - e'^2(0.4494968) - e'^2(0.797303) \\
&\qquad\qquad - e'^2(28.992915) - e'^2(41.26516)\Big\}
\end{aligned}\right.
$$

This gives by reduction

$$
(28)\qquad \delta\frac{d\omega}{dt} = \frac{\bar{m}^4}{\mu^2}n\Big\{126.3537 - 759.608\,e'^2\Big\}
$$

Equation (5) also reduces to the following.

$$\begin{aligned}\delta^2 \frac{d\omega}{dt} = \frac{m^6}{\mu^3} n \Big\{ & \{3.538562 + 574.9660\, e'^2\} + \{294.3489 + 3167.188\, e'^2\} \\ & + \{7.90392 + 83.5002\, e'^2\} - \{41.36963 - 146.9083\, e'^2\} + e'^2(109.3733) \\ & - e'^2(5394.876) + e'^2(6998.677) + \{26.16101 + 6977.880\, e'^2\} \\ & + \{2.118858 - 7.58874\, e'^2\} - \{6.23617 - 21.82768\, e'^2\} + e'^2(148.157) \\ & + e'^2(1228.028) - e'^2(96.7988) - e'^2(0.11968) - e'^2(888.774) \\ & - e'^2(176.0650) + \{33.7491 - 170.0128\, e'^2\} - \{0.837826 - 17.0908\, e'^2\} \\ & + e'^2(138.0166) + e'^2(206.1294) - e'^2(213.3913) - \{132.0807 + 1700.365\, e'^2\} \\ & + \{0.196671 + 244.3913\, e'^2\} + \{1.930740 + 157.8669\, e'^2\} + e'^2(95.26005) \\ & + e'^2(652.05097) - e'^2(25.31389) + e'^2(29.13172) - e'^2(176.55084) \\ & + e'^2(137.07861) + \{657.8323 + 5353.883\, e'^2\} + e'^2(47.39863) \\ & - e'^2(15051.47) + e'^2(16370.29) + \{39.70451 + 18538.33\, e'^2) \\ & + \{1.539466 - 5.38812\, e'^2\} + \{5.38298 - 18.81044\, e'^2\} - e'^2(10.2131) \\ & - e'^2(332.7871) - e'^2(128.2897) - e'^2(5.38632) - e'^2(1307.937) - e'^2(115.6271) \\ & - \{322.3264 + 2943.040\, e'^2\} + \{0.112992 + 338.9663\, e'^2\} + e'^2(58.51296) \\ & + \{1.988991 + 542.9333\, e'^2\} + e'^2(380.3289) - e'^2(35.03067) \\ & - e'^2(114.81091) - e'^2(261.26226) - e'^2(704.35394) \Big\} \end{aligned} \tag{29}$$

By reduction this expression becomes

$$\delta^2 \frac{d\omega}{dt} = \frac{m^6}{\mu^3} n \Big\{ 574.2611 + 32849.792\, e'^2 \Big\} \tag{30}$$

If we now take the sum of equations (26), (28) and (30), we shall obtain for the complete value of $\frac{d\omega}{dt}$

$$\begin{aligned}\frac{d\omega}{dt} &= n \Big\{ \tfrac{3}{4} \frac{m^2}{\mu} + 126.3537 \frac{m^4}{\mu^2} + 574.2611 \frac{m^6}{\mu^3} \Big\} \\ &\quad + n \Big\{ \tfrac{9}{8} \frac{m^2}{\mu} - 759.608 \frac{m^4}{\mu^2} + 32849.792 \frac{m^6}{\mu^3} \Big\} e'^2 \end{aligned} \tag{31}$$

Now since $\frac{m^2}{\mu} = 0.0055952223$, equation (31) will become $\frac{d\omega}{dt} = n\{0.00825274 - 0.0117318\, e'^2\}$

$$= n\{0.00825274 - 0.0117318\, e_0'^2 - 0.0117318(e'^2 - e_0'^2)\} \tag{32}$$

in which e'_0 is the value of e' at the epoch, when the secular term is supposed to vanish.

Equation (32) gives by integration

$$\omega = \omega_0 + \{0.00825274 - 0.0117318\, e_0'^2\} nt - 0.0117318\, n \int (e'^2 - e_0'^2)\, dt \tag{33}$$

If we put for e' its value in 1850, and for n the moon's mean motion in a Julian year, we shall have

$$e'_0 = 0.0167712, \qquad n = 17325593'';$$

and equation (33) will become, in which t denotes the number of Julian years,

$$(34) \qquad \omega = \omega_0 + 142925'' \cdot t - 203260'' \int (e'^2 - e_0'^2)\, dt$$

The coefficient of t corresponds to a daily motion of the perigee amounting to 391″.3; whereas the true motion is about 400″.9. Hence it follows that the three terms of the series which we have computed give the motion of the perigee within $\frac{1}{42}$ part of its actual motion. If we suppose the secular term to be given with the same degree of accuracy, its true value would be $-208100'' \int (e'^2 - e_0'^2)\, dt$. But I have supposed, from inductive reasoning, that the sum of the remaining terms of the series would increase the coefficient of the secular term by very nearly $\frac{1}{12}$ of its value; and that the secular variation of the longitude of the perigee is given by the equation.

$$(35) \qquad \delta\omega = -219880'' \int (e'^2 - e_0'^2)\, dt$$

6. In the same manner I have computed the motion of the moon's node, and have obtained the following value (36)

$$\frac{d\Omega}{dt} = \frac{m^2}{\mu} n \Big\{ -\tfrac{3}{4} - \tfrac{9}{8} e'^2 \Big\} + \frac{m^4}{\mu^2} n \Big\{ 4.088874 - 22.6974\, e'^2 \Big\} + \frac{m^6}{\mu^3} n \Big\{ -17.6705 - 173.7[illegible]\, e'^2 \Big\}$$

If we substitue the value of $\frac{m^2}{\mu}$, this equation will become

$$\begin{aligned}\frac{d\Omega}{dt} &= -0.004071503\, n \\ &\quad - n\{0.00629463 + 0.00071058 + 0.0000829 [illegible]\} e'^2 \\ &= -0.004071503\, n - 0.00708819\, n\, e'^2 \end{aligned} \tag{37}$$

Since each term in the coefficient of e'^2 is about [illegible] of the preceding term, we may compute another term by induction, and we shall obtain for the secular motion of the node

$$\begin{aligned}\delta\Omega &= -0.00709719\, n \int (e'^2 - e_0'^2)\, dt \\ &= -122965'' \int (e'^2 - e_0'^2)\, dt \end{aligned} \tag{38}$$

7. In chapter IX of my *Theory of the Moon's Motion*, I have found the secular equation of the moon's longitude, depending on the eccentricity of the earth's orbit to be

$$\delta v = -111108''.5 \int (e'^2 - e_0'^2)\, dt = +7''.889\, t^2 \text{ very nearly.}$$

I also found a small secular equation in the longitude arising from the secular variation of the obliquity of the ecliptic, which amounts to $0''.1979 \cdot i^2$ very nearly. Hence the secular equation of the moon's longitude is

$$\delta v = +8''.087 \cdot i^2 = -113900'' \int (e'^2 - e'^2_0)\, dt \qquad (39)$$

8 We shall, therefore, in the remainder of this investigation, assume that the three secular equations which affect the moon's motion have the following values, namely.

$$(40) \qquad \left\{ \begin{aligned} \delta v &= -113900'' \int (e'^2 - e'^2_0)\, dt \\ \delta \omega &= -219880'' \int (e'^2 - e'^2_0)\, dt \\ \delta \Omega &= -122965'' \int (e'^2 - e'^2_0)\, dt \end{aligned} \right.$$

Hansen, in his *Tables de la Lune*, has used the following, for the first terms of the sidereal secular equations of the moon's motion. (41)

$$\delta v = +12''.180 \cdot i^2, \quad \delta \omega = -37''.255 . i^2, \quad \delta \Omega = +7''.068 . i^2.$$

If the values of the secular inequalities found above are correct, it follows that Hansen's secular equation of the moon's longitude is too large by $4''.093 \cdot i^2$; and the correction to his longitude of the perigee amounts to $+52''.865 \cdot i^2$. This large correction to the longitude of the moon's perigee would amount to nearly nine degrees in the course of twenty-five centuries, and be sufficient to entirely change the character of any distant solar eclipse. It is therefore no wonder that Hansen's *Tables* completely fail to satisfy the records of the ancient solar eclipses that have been handed down to us. And it has seemed to me that if the corrections which I have indicated above are not well founded the calculations of the ancient eclipses which are based on them would differ far more widely from the records than the calculations based on Hansen's *Tables* themselves.

9. I have therefore taken as the basis of my calculations, the mean sidereal motions of the sun and moon, and also of the moon's perigee and node, as given in the Introduction to Hansen's *Tables*. Equations (40) have given me the secular variations in the moon's motion; and the precession of the equinoxes, the obliquity of ecliptic, the longitude of the sun's perigee, and the eccentricity of the earth's orbit have been taken from my Memoir on the *Secular Variations of the Orbits of the Eight Principal Planets*, which is published as no. 232 of the *Smithsonian Contributions to Knowledge*.

The integral $\int (e'^2 - e'^2_0)\, dt$ has been taken from the table on page 362 of my *Theory of the Moon's Motion*. For the periodic equations I have taken sixty of the most important equations for the longitude, and forty-seven for the latitude, from Delaunay's *Théorie du Mouvement de la Lune*. These equations include all the inequalities whose coefficients exceed one second of arc, and also several of smaller value. I have neglected the equation of the moon's latitude arising from the oblateness of the earth, and have reduced the similar equation of the longitude in the ratio of 13 : 19, in order to conform to the result of my investigation which is given in nos. 145–149 of this Journal. I have also neglected Hansen's equations of long-period arising from the action of *Venus* on the moon, as I have shown in nos. 158, 159 and 163 of this Journal that the inequalities in the moon's motion produced by the attraction of the planets are wholly insensible.

10. The materials for discussion have been drawn from various sources. I have consulted Baily's Memoir on the eclipse of Thales in the *Philosophical Transactions* for 1811; Airy, on the eclipses of Agathocles, Thales and Xerxes, in the *Philosophical Transactions* for 1853; Hansen's *Darlegung*, &c.; Newcomb's *Researches on the Motion of the Moon;* and a little work on *Eclipses Past and Future* by S. J. Johnson. These works, in the light of recent developments in the lunar theory, are chiefly valuable on account of the discussions of the historical narratives of the eclipses which they contain

11. From these several works I have prepared the following list of solar eclipses which occurred between the years A.D. 1140 and B.C. 1184; and in the same table I have given the elements of the earth's orbit at the times of the several eclipses, and which are necessary for their computation.

Date	No.	ψ'	ε	ω'	e'
		° ′ ″	° ′ ″	° ′ ″	
A.D. 1140 Mar. 20	1	— 9 53 20.4	23 33 17.3	278 3 3.4	0.0170600
A.D. 1030 Aug. 30	2	11 24 45.3	23 34 10.3	277 41 46.6	0.0171036
A.D. 364 June 16	3	20 39 41.6	23 39 29.2	275 32 58.8	0.0173607
A.D. 360 Aug. 28	4	20 42 51.3	23 39 31.0	275 32 14.8	0.0173622
A.D. 348 Oct. 9	5	20 52 44.6	23 39 36.6	275 29 57.4	0.0173667
B.C. 309 Aug. 15	6	29 58 32.2	23 44 42.3	273 23 50.4	0.0176084
B.C. 423 Mar. 21	7	31 33 25.5	23 45 34.2	273 1 59.7	0.0176492
B.C. 430 Aug. 3	8	31 38 54.0	23 45 37.2	273 0 43.8	0.0176516
B.C. 480 Apr. 19	9	32 21 4.7	23 46 0.0	272 51 1.4	0.0176696
B.C. 546 Oct. 23	10	33 14 51.4	23 46 29.5	272 38 39.1	0.0176926
B.C. 556 May 19	11	33 23 29.8	23 46 34.2	272 36 40.0	0.0176963
B.C. 584 May 28	12	33 46 40.4	23 46 46.7	272 31 20.4	0.0177061
B.C. 602 May 18	13	34 1 36.4	23 46 54.8	272 27 54.5	0.0177124
B.C. 609 Sept. 30	14	34 7 5.9	23 46 57.8	272 26 38.8	0.0177147
B.C. 762 June 15	15	36 14 2.4	23 48 6.0	271 57 29.5	0.0177682
B.C. 1184 Aug. 28	16	—42 2 56.2	23 51 9.3	270 37 32.8	0.0179116

In the above table ψ' denotes the precession of the equinoxes between Jan. 1, 1850, and the date of the eclipse; and ε, ω' and e', respectively denote the obliquity of the ecliptic, the longitude of the sun's perigee, and the eccentricity of the earth's orbit.

In the following table I have given the corrections to the time of mean conjunction of the sun and moon, to their mean longitudes, and to the longitudes of the perigee and node of the moon's orbit, arising from the secular variations of the elements; together with the integral $\int (e'^2 - e_0'^2)dt$ by means of which they are determined.

No.	$-\int (e'^2-e_0'^2)\,dt$	ΔT	$\Delta nt = \Delta n't$	$\Delta\omega$	$\Delta\Omega$
		d	°	°	°
1	0.003488	—0.00905	—0.00892	+0.2119	+0.1196
2	0.004639	0.01201	0.01187	0.2850	0.1591
3	0.015115	0.03923	0.03866	0.9180	0.5181
4	0.015190	0.03942	0.03886	0.9234	0.5209
5	0.015433	0.04005	0.03948	0.9381	0.5293
6	0.031599	0.08201	0.08083	1.9209	1.0837
7	0.034979	0.09078	0.08948	2.1263	1.1996
8	0.035180	0.09130	0.08999	2.1385	1.2065
9	0.036740	0.09535	0.09398	2.2334	1.2600
10	0.038776	0.10064	0.09919	2.3572	1.3298
11	0.039109	0.10150	0.10004	2.3774	1.3350
12	0.040006	0.10383	0.10233	2.4320	1.3720
13	0.040589	0.10534	0.10383	2.4674	1.3920
14	0.040806	0.10590	0.10438	2.4806	1.3994
15	0.045944	0.11924	0.11752	2.7929	1.5756
16	0.061570	—0.15979	—0.15750	+3.7427	+2.1115

12. A full and satisfactory discussion of some of the ancient eclipses is a matter of considerable difficulty. This difficulty arises from the fact that the historical narratives do not enable us to fix the date of the eclipse, nor even the locality where it was observed, except within widely extended limits. For example, the eclipse which is said to have been predicted by THALES, and which put an end to a sanguinary battle between the *Medes* and *Lydians*, has been assigned by historians to various dates between the years 581 B.C. and 626 B.C.; and the place where the battle was fought has the boundaries of Asia Minor for its limits. The three eclipses which I have numbered 12, 13 and 14 in the preceding table, are those which seem to best satisfy the historical narrative. As another example, we may refer to the eclipse encountered by the fleet of AGATHOCLES while on its voyage from Sicily to Africa. Although the date of this eclipse is well known, it is still a matter of controversy whether AGATHOCLES sailed to the northward or southward of Sicily; and this question can only be settled by the eclipse itself. Again, THUCYDIDES states that in the summer of the first year of the *Peloponnesian war* an eclipse occurred at Athens, which was so great that some of the stars appeared. Now the date of this war seems to be very satisfactorily known; but astronomers have never yet been able to find an eclipse of sufficient magnitude at Athens, to produce the phenomena described by the historian.

On account of these various difficulties and incompatibilities, Professor NEWCOMB has contented himself with a critical discussion of the historical narratives, from which he concludes that the evidence concerning the eclipses is too uncertain and indefinite to be worthy of further consideration. This is hardly to be wondered at, when we consider the very imperfect tables of the moon's motion which he employed as the basis of his investigation. I shall, however, in what follows, confine myself wholly to this and other similar material which has been rejected by Professor NEWCOMB; and I hope to show, to the satisfaction of astronomers and historians, that the narratives concerning these eclipses are not only consistent with themselves, but that they may very properly be classed among the choicest historical jewels recorded in the Grecian classics.

(*Continued in no. 221.*)

THE LUNAR APPULSE OF 1890 JUNE 2.

BY E. E. BARNARD.

At $10^h\ 15^m$ Standard Pacific Time = $18^h\ 45^m$ Gr. M.T. June 2, a rather heavy shade was observed on the southern limb of the moon; it covered about $\frac{1}{10}$ or $\frac{2}{10}$ of the disc. There was no decided shadow, only a diffused heavy shade perhaps as deep, or slightly deeper in tint, than the lunar plains, but so conspicuous that even a chance look at the moon could not fail to detect it. This was the lunar appulse spoken of in the *American Ephemeris* for 1890, p. 115.

Mt. Hamilton, 1890 *June* 3.

OBSERVATIONS OF COMET *a* 1890,

MADE AT THE SHATTUCK OBSERVATORY OF DARTMOUTH COLLEGE WITH THE 9.4-INCH EQUATORIAL AND RING-MICROMETER,

BY EDWIN B. FROST.

1890 Greenwich M.T.	✱	No. Comp.	☄—✱ Δα	☄—✱ Δδ	☄'s apparent α	☄'s apparent δ	log *p*Δ for α	log *p*Δ for δ
d h m s			m s	′ ″	h m s	° ′ ″		
April 15 20 33 39	*a*	12 . 6	−0 48.81	+ 5 37.8	21 9 36.08	18 54 56.8	*n*9.576	0.663
18 20 25 54	*b*	4	+0 38.36	+11 44.1	21 8 33.04	20 48 35.8	*n*9.566	0.641
20 55 20	*b*	4	+0 38.26	+12 35.0	21 8 32.94	20 49 26.7	*n*9.522	0.618
20 20 45 58	*c*	7	+2 4.65	+ 8 4.8	21 7 38.86	22 8 14.1	*n*9.536	0.603
22 20 42 17	*d*	12	−0 26.20	−12 53.2	21 6 33.50	23 29 34.7	*n*9.567	0.602
28 20 0 44	*e*	7	+0 38.79	− 4 19.9	21 2 13.50	27 53 50.4	*n*9.577	0.536
20 37 56	*f*	4	−1 15.08	−15 31.4	21 2 12.88	27 54 54.0	*n*9.196	0.489
20 41 3	*e*	3	+0 37.33	− 3 0.0	21 2 12.01	27 55 10.3	*n*9.496	0.489

Mean Places for 1890.0 of Comparison-Stars.

✱	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
a	21 10 25.53	−0.64	18 49 33.3	−14.3	Weisse's Bessel, XXI 195
b	21 7 55.25	−0.57	20 37 6.5	−14.8	Weisse's Bessel, XXI 129
c	21 5 34.70	−0.49	22 0 24.2	−14.9	Greenwich 7-yr. Catal., 2401
d	21 7 0.14	−0.44	23 42 43.1	−15.2	Weisse's Bessel, XXI 105
e	21 1 34.92	−0.21	27 58 26.1	−15.8	Lalande 40934
f	21 3 28.19	−0.23	28 10 41.2	−15.8	Yarnall (F) 9487

These observations have been corrected for refraction, proper motion, and when it has been significant, for curvature.

The micrometer is a double ring, and I have therefore used the outer ring for Δα, and the inner for Δδ. The observations on April 18, 22, and the last two of April 28, were made with the outer ring only. The last two observations are entitled to the least weight of any in the set, and I presume that proper motion has changed the place of Lal. 40934.

OBSERVATIONS OF COMET *a* 1890,

MADE AT THE U. S. NAVAL OBSERVATORY WITH THE 9.6-INCH EQUATORIAL,

BY PROF. EDGAR FRISBY.

[Communicated by the Superintendent.]

1890 Washington M.T.	✱	No. Comp.	☄—✱ Δα	☄—✱ Δδ	☄'s apparent α	☄'s apparent δ	log *p*Δ for α	log *p*Δ for δ
d h m s			m s	′ ″	h m s	° ′ ″		
May 28 11 28 38.0	1	18 , 4	+1 18.37	−3 31.4	19 43 14.38	+55 15 39.5	*n*9.8313	8.7915
29 10 5 6.7	2	18 , 4	−1 1.39	+3 5.1	19 37 40.34	+56 6 40.6	*n*9.9023	0.2192
June 5 11 12 55.9	3	5 , 1	−1 47.10	+0 53.6	18 47 41.99	+61 51 46.8	*n*9.6008	*n*0.4320
7 9 48 12.6	4	20 , 4	−0 10.41	−8 42.9	18 27 31.65	+62 55 16.1	*n*9.9058	*n*0.0758

Mean Places for 1890.0 of Comparison Stars.

✱	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	19 41 54.33	+1.68	+55 19 24.4	−13.5	Oe. Arg. N 19604
2	19 38 39.97	+1.76	+56 3 48.8	−13.3	Oe. Arg. N 19552
3	18 49 26.40	+2.69	+61 51 1.9	− 8.7	Oe. Arg. N 18736
4	18 27 39.15	+2.91	+63 4 5.3	− 6.3	Bonn VI, +63° 1428

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ON THE SECULAR AND LONG-PERIOD INEQUALITIES IN THE MOON'S MOTION,

By JOHN N. STOCKWELL.

(*Continued from no. 220.*)

13. I shall now proceed to a particular discussion of the several eclipses given in the preceding table; commencing with the eclipse which is said to have been predicted by Thales. The narrative concerning this eclipse is given by Herodotus, i. 74; and the following translation is by Professor Huntington of the Columbian University, as given on page 28 of Newcomb's *Researches on the Motion of the Moon*:

"Now after this (for Alyattes did not by any means surrender the Scythians at the demand of Cyaxares) there was war between the Lydians and the Medes for the space of five years, in which [period] the Medes often conquered the Lydians, and the Lydians, in turn, the Medes. And, in this time, they also had a night-engagement; for as they were protracting the war with equal success on each side, in a battle that occurred in the sixth year, it happened, as the armies engaged, that the day was suddenly turned into night. Now this change of the day [into night] Thales, the Milesian, had predicted to the Ionians, placing as the limit of the period [within which it would take place] this very year in which it did actually occur. Now, both the Lydians and the Medes, when they saw night coming on, instead of day, ceased from battle, and both parties were more eager to make peace with each other."

14. The question as to the date of this eclipse has given rise to much discussion in modern times. Mr. Francis Baily, early in the present century, discussed, by means of the best astronomical tables of his time, all the solar eclipses which happened between the years 629 B.C. and 595 B.C., and found only one which was total in, or near, any part of Asia Minor. He was led, by means of what appear to be very legitimate historical considerations, to fix the date of the eclipse between the years above mentioned; and as the eclipse of 609, Sept. 30, was computed to be total at the mouth of the river Halys, and in the north-eastern part of Asia Minor, he was led to consider that as the true date of the battle. And that date has been considered by historians as the true date of the battle, for more than forty years after the publication of Baily's investigations. But when Baily applied the same *Tables of the Moon* to the investigation of the eclipse of Agathocles, B.C. 309 August 15, they carried the moon's shadow so far south of Sicily that it was not possible for it to be very nearly total at any point where it was possible to locate the fleet of Agathocles. It therefore followed that the two eclipses were incompatible with each other, and that they could not be reconciled with the received interpretations of the narratives.

Mr. Airy discussed the same eclipses in 1853. He assumed that the eclipse of Agathocles should be considered as the true cardinal eclipse of antiquity; and adjusted the lunar tables so as to represent that eclipse; but this adjustment served to throw the moon's shadow in the eclipse of 609 September 30 far to the northward of the Black Sea; so that it could no longer be considered as the eclipse of Thales. It was therefore necessary for Mr. Airy to seek for another eclipse to satisfy the narrative concerning the eclipse of Thales. This he was unable to do without coming ten years beyond the historical limit assigned by Baily. He found, however, that in B.C. 584 May 28 there was a total eclipse of the sun visible in the extreme southern and western part of Asia Minor; and hence this date has been mostly given in recent times as the true date of the eclipse.

15. But the supposition that this is really the eclipse of Thales is not wholly free from difficulties. It occurred almost at the instant of sunset in Asia Minor, and this circumstance has led Professor Newcomb to doubt the reality of the occurrence of any eclipse at all; since the existence of a dense bank of clouds in the vicinity of the sun would apparently hasten the approach of night. He also found by means of his corrected tables of the moon's motion, that the eclipse was total at sunset, almost at the southern limit of the Mediterranean Sea, not very far distant from Alexandria. Hence it is evident that this eclipse was not total to any part of Asia Minor; and consequently could not be the eclipse of Thales.

16. But there are still other difficulties in the way of this being regarded as the eclipse of Thales. A natural inference from the narrative is, that the eclipse occurred soon after the battle began; and it is not usual for great battles

to be postponed till near the close of day, as night itself might speedily put a stop to the fighting before any material advantage had been gained on either side. The lateness of the hour at which the eclipse took place would therefore seem to preclude the possibility of this being the eclipse of THALES.

17. I shall now proceed to give an account of my own investigations on the subject. The basis of my calculations is explained in §9 of this paper. A preliminary examination of the eclipse of B.C. 584 May 28, shows that the sun set throughout Asia Minor long before the eclipse commenced. I therefore no longer considered that as the eclipse of THALES. On the other hand, my calculation in regard to the eclipse of B.C. 609 September 30 shows that the shadow passed wholly to the south of Asia Minor; while the shadow in the eclipse of AGATHOCLES passed centrally across the Island of Sicily, a little to the northward of Syracuse. Moreover Mr. CELORIA of Milan has inferred from some recent historical investigations that the moon's shadow in the eclipse of AGATHOCLES passed so far north as to cover the Hellespont. Assuming this inference of CELORIA to be correct, it occurred to me that a slight change in the place of the moon's node would suffice to carry the shadow in the eclipse of B.C. 609 directly across the central parts of Asia Minor. The calculation of the effect of such a change in the place of the node upon the path of the moon's shadow proved the conjecture to be true; and also showed that the two eclipses were no longer incompatible with each other.

I next computed the eclipse of B.C. 430 August 3, which occurred during the first year of the Peloponnesian war. This eclipse is usually referred to as the eclipse of PERICLES, on account of his effort to allay the fears of his pilot at the time of its occurrence. My elements showed that the eclipse was annular; and also that the center of the annulus passed so near to Athens that at least ten digits of the sun must have been covered. I also computed the central path of the annulus by using HANSEN's secular variations of the elements, and I found the path to be situated a little beyond the Sea of Azov; while my elements caused the central path to pass nearly midway between Athens and the Hellespont. It therefore seemed possible that a small change in the elements of the moon's motion would bring the three eclipses into perfect harmony.

18. In order to ascertain whether such changes were possible, I constructed maps showing the paths of the three eclipses corresponding to the assumed elements. I then assumed that the mean motion of the moon required a small correction, and computed the path of the shadow resulting from such a correction. The same process was repeated with respect to small corrections to the mean motions of the perigee and node. In discussing the results of such changes it was found that no appreciable correction to the moon's mean motion was required; but a decided improvement would result by supposing

$$\Delta\omega = +0''.750048 \quad \text{and} \quad \Delta\Omega = +0''.9020712$$

in which $\Delta\omega$ and $\Delta\Omega$ denote the correction to the mean motion of the perigee and node in a Julian year.

19. I shall now give the resulting elements of each eclipse, taking them in the reverse order of their occurrence.

In what follows t denotes the Washington mean time of conjunction of moon and sun in right-ascension, α, α', δ, δ', D and D', denote the right-ascension, declination and semidiameters of the moon and sun respectively, and π denotes the moon's parallax. The parallax of the sun has been neglected, it being too small to affect the results to any sensible amount. Also λ and ϕ denote the longitude and latitude of the shadow on the earth measured from the meridian of Greenwich, west longitudes being supposed positive. The letter Δ placed before a quantity denotes the hourly variation of that quantity.

20. Eclipse number 1 is said by HALLEY to have been total in London. S. J. JOHNSON, in his *Eclipses Past and Future*, gives the following: "A.D. 1140 March 20. A total eclipse in England. The *Saxon Chronicle* relates 'In the Lent, the sun and the day darkened, about the noon-tide of the day, when men were eating, and they lighted candles to eat by. That was the 13th day before the calends of April. Men were very much struck with wonder.' William of Malmesbury records 'During this year, in Lent, on the 13th of the calends of April, there was an eclipse throughout England, as I have heard. With us and with all our neighbors, at the ninth hour of the fourth day of the week, the obscuration was so remarkable, that people said chaos was come again, since it was Lent. Afterwards, learning the cause, they went out and beheld the stars around the sun.'"

JOHNSON then states that according to his calculation the greatest obscuration at London was at $2^h\ 36^m$, at which time a narrow crescent was uncovered at the south of the sun, showing that the line of totality must have gone north of London, a result not agreeing with Dr. HALLEY's.

For this eclipse I find the following elements:

$$t = \text{March } 20 \quad 21^h\ 9^m\ 52^s.7$$

$$\begin{array}{llll} \alpha = \alpha' = & 6^\circ\ \ 2'\ 16''.4 & D = 16'\ 42''.1 & \Delta\alpha = \ \ 36'\ 13''.1 \\ \quad\ \ \delta = & +3\ \ 16\ \ 10\ .4 & D' = 16\ \ \ 0\ .0 & \Delta\alpha' = \ \ \ 2\ \ 16\ .0 \\ \quad\ \ \delta' = & +2\ \ 37\ \ 31\ .8 & \pi = 61\ \ 17\ .3 & \Delta\delta = +11\ \ 51\ .1 \\ & & & \Delta\delta' = +\ 0\ \ 58\ .8 \end{array}$$

From these elements I find, for central eclipse at noon,

$$\lambda = +33^\circ\ 8', \qquad \phi = +\ 41^\circ\ 43'$$

The path of central eclipse across England may be determined by means of the following coordinates:

T	λ	ϕ
h m	° ′	° ′
21 52	+5 29	+51 5
21 56	+0 58	52 1
22 0	—4 18	+52 53

The breadth of the shadow was 126 miles. If these points be laid down on a map of England it will be seen that the line of central eclipse passes directly over Cambridge; and also that the southern limit of the shadow passes from Land's End on the west, through the northern point of Sheppy Island on the east. It therefore follows that the shadow extended to the distance of about fifteen miles to the south of London, and confirms the statement of HALLEY in regard to its totality at that place.

21. Eclipse no. 2 is not mentioned by JOHNSON. It occurred A.D. 1030 August 30; and has been pretty fully discussed by Mr. AIRY in volume XXVI of the *Memoirs of the Royal Astronomical Society;* and also still later by M. HANSEN, in his *Darlegung*, which was published in 1864. It is usually designated as the *eclipse of Stiklastad;* on account of its having occurred while a battle was being fought at that place.

The tradition concerning it is given by HANSEN in volume II, page 388, of his *Darlegung*, and is as follows:

"King OLAF of Norway, afterwards sainted, was engaged in war with some rebellious peasants, and fell in a battle fought at Stiklastad. During this battle an eclipse happened which, according to the narration of chroniclers, caused, in an unclouded sky, such a darkness, that friends and foes could not tell themselves apart. The darkness is said to have lasted 1½ hours, and one author asserts, that it was pitch dark from 9½ A.M. until 3 P.M."

It is evident from this statement that the narratives concerning this eclipse are not wholly free from exaggeration; but the fact of the occurrence of the eclipse cannot be disputed.

According to HANSEN's computation the northern limit of the moon's shadow passed a hundred miles to the south of Stiklastad. The eclipse, therefore, lacked considerable of being total at that place, although it must have beeen a very large one.

According to my calculations the elements of the eclipse are as follows:

$t =$ August 30 $20^h\ 28^m.8$

$\alpha = \alpha' = 164^\circ 21'\ 5''.8$ $\quad D = 15'\,53''.1$ $\quad \Delta a = 1991''.9$

$\delta = +\ 7\ 37\ 50.2$ $\quad D' = 15\ 58.5$ $\quad \Delta a' = 137.3$

$\delta' = +\ 6\ 42\ 40.6$ $\quad \pi = 58\ 17.1$ $\quad \Delta\delta = -\ 623.1$

$\Delta\delta' = -\ 56.9$

Supposing the earth to be spherical, we get for central eclipse at noon $\lambda = +21^\circ\ 50'$, $\phi = +77^\circ\ 52'$. And for different times denoted by T we get

T	λ	ϕ
h m	° ′	° ′
21 0	− 7 42	+65 0
21 4	10 11	63 31
21 8	−12 37	+62 6

According to HANSEN, we have for Stiklasthd

$$\lambda = -11^\circ\ 35', \qquad \phi = +63^\circ\ 48'$$

If these points be charted on a map of the country it will easily be seen that the center passed very nearly one degree of a great circle from Stiklastad. But the oblateness of the earth has an important effect upon the path of the shadow in such high latitudes. I have therefore computed the position of the center of the shadow at $21^h\ 4^m$, allowing for the oblateness, which I have supposed to be equal to $\frac{1}{300}$; and I have found for that instant

$$\lambda = -11^\circ\ 28', \qquad \phi = +64^\circ\ 9'$$

If we draw a line through this point parallel to the path through the other three points, it will be easily seen that the shadow approaches Stiklastad within about *one-tenth* of a degree. The eclipse was therefore practically total at that point. It should be observed, however, that the elliptical shadow on the earth was extremely small, not exceeding two and one-half miles in breadth by six in length.

22. Eclipse number 3, A.D. 364 June 16, was observed at Alexandria by THEON, who states that it began at $3^h\ 18^m$, and ended at $5^h\ 15^m$. The duration was therefore $1^h\ 57^m$. I find by computation that it commenced at $4^h\ 10^m$, and ended at $5^h\ 56^m$, having a duration of $1^h\ 46^m$. Its magnitude at $5^h\ 8^m$ was 5.45 digits at Alexandria. The line of totality in this eclipse passed from the mouth of the Niemen river on the Baltic, through the territory of Russia, and entered the Caspian Sea near the mouth of the Volga. It was central and total at noon in west longitude 25° 5′, and north latitude 58° 54′.

23. Eclipses numbered 4 and 5 have been computed for the purpose of throwing light on a statement made by AMMIANUS MARCELLINUS (Book XX, Chap. 3). The work of AMMIANUS not being accessible, the following translation has kindly been furnished me by the Editor of this Journal, and is as follows:

"At the same time the sky in the east was perceived to be covered with a thick darkness; and from daybreak until noon the stars were visible throughout. And as an addition to these terrors, while the light of heaven was thus withdrawn, and the world almost buried in clouds, men from the length of the eclipse began to believe that the sun had wholly disappeared. Presently, however, it was seen like a new moon, then like a half-moon, and at last it was restored entire."

In regard to this statement, the Editor makes the following judicious remarks:

"The duration from daybreak to noon ought to render this eclipse a rather prominent one in history; but there is always the possibility that AMMIANUS may have slightly exaggerated the stories that reached him. By 'the east' the commentators seem to understand Mesopotamia, and the Roman dominion there extended only to the river Tigris. The date 'at the same time' is interpreted as A.D. 360, and seems to be pretty well determined."

If the phenomenon described by AMMIANUS were really due to an eclipse of the sun, its supposed date must be considerably in error. I find that the eclipse of A.D. 360 August 28, was central at noon in longitude 129° 22′ east of Greenwich, and in north latitude 26° 44′. It was also annular, the annulus being quite large. It also occurred before sunrise in any part of Mesopotamia, so that it could not possibly have occasioned the phenomenon described by AMMIANUS.

I find, however, that eclipse number 5, A.D. 348 October 9, satisfies the phenomenon so far as a solar eclipse is capable of doing so. It occurred in the morning, and the sun was totally eclipsed in the eastern parts of Mesopotamia at $9^h\ 50^m$. The shadow was quite large, being 85 miles in breadth by 140 miles in length while on its passage through Mesopotamia. The following are the calculated positions of the central line.

T	λ	ϕ
h m	° ′	° ′
13 50	—33 30	+43 22
11 0	41 36	38 54
14 10	47 19	34 43
14 20	51 40	31 3
14 40	58 21	24 27
15 0	—63 45	+18 31

The path of the total eclipse is shown by the map which accompanies this paper.

24. Eclipse number 6, B.C. 309 August 15, is the celebrated eclipse of AGATHOCLES. I have used this eclipse to correct the elements of the moon's motion, in such manner that the shadow should cover the Hellespont. With the corrected elements the shadow passes wholly to the north of Sicily. I find, however, that the magnitude of the eclipse at a point one degree north of Syracuse would be 11.55 digits. It therefore seems certain that AGATHOCLES sailed to the north of Sicily when on his voyage to Africa.

I also find for this eclipse

$$
\begin{array}{llll}
t = 16^h\ 19^m\ 42^s & & & \\
\alpha = \alpha' = & 139^\circ\ 8'\ 50''.6 & D = 16'\ 39''.4 & \Delta\alpha = \ 38'\ 36''.0 \\
\delta = + & 16\ 24\ 34\ .6 & D' = 15\ 57\ .7 & \Delta\alpha' = \ 2\ 26\ .5 \\
\delta' = + & 16\ \ 3\ 11\ .5 & \pi = 61\ \ 9\ .9 & \Delta\delta = -\ 8\ 10\ .5 \\
 & & & \Delta\delta' = -\ 0\ 45\ .0
\end{array}
$$

For central eclipse at noon we have $\lambda = -38^\circ\ 36'$, $\phi = +36^\circ\ 31'$; and the coordinates of the central path at different times are as follows:

T	λ	ϕ	T	λ	ϕ
h m	° ′	° ′	h m	° ′	° ′
15 28	—11 49	+40 1	16 24	—40 25	+35 58
15 36	16 55	39 57	16 32	43 41	34 52
15 44	21 33	39 40	16 40	46 51	33 39
15 52	25 49	39 12	16 48	50 0	32 20
16 0	29 45	38 36	16 56	53 8	30 54
16 8	33 27	37 51	17 4	—53 16	+29 23
16 16	—37 1	+36 58			

The fleet of AGATHOCLES was therefore probably enveloped in the darkness of the eclipse at $9^h\ 42^m$ in the morning; which is more than *two hours later* than the time indicated by Professor AIRY. The path and magnitude of the shadow is well illustrated by means of the accompanying map.

25. Eclipse number 7, B.C. 423 March 21, is the one referred to by THUCYDIDES as having occurred at the beginning of the eighth year of the Peloponnesian war. As he has given no particulars concerning the time of day at which it took place, nor told us anything in regard to its magnitude at Athens, a brief notice of this eclipse is all that is required. I find that the eclipse was a very large annular one, in which the central line passed through the kingdom of Denmark, a little to the north of Copenhagen; thence through Sweden directly over Stockholm. It was central at noon in east longitude 56° 3′, and latitude 88°; and the axis of the shadow left the earth at the north pole. Its greatest magnitude at Athens was at $8^h\ 43^m$ in the morning; and its magnitude at that time 7.42 digits on the sun's northern limb. These particulars fully satisfy the account of the eclipse given by THUCYDIDES.

26. Eclipse number 8 B.C. 430 August 3, is the one which occurred during the summer of the first year of the Peloponnesian war. It was visible at Athens; and THUCYDIDES states that the darkness was so great that some of the stars were visible. Astronomers have found much difficulty in reconciling the statement of the historian with the facts deduced from the lunar tables; for it has been found, by calculations based on the best lunar tables of the present time, that the magnitude of the eclipse at Athens could not have exceeded about seven-tenths of the sun's diameter: and with so much of the sun uncovered it would be impossible for any of the stars to appear. These considerations have led Mr. S. J. JOHNSON to suppose that an eclipse which occurred two years earlier, on March 30, might possibly be the one referred to by the historian. But Mr. W. T. LYNN, in volume VII of the *Observatory* has very clearly shown, from other considerations, that the eclipse could not have occurred so early in the year as Mr. JOHNSON supposes. All doubt, however, as to the identity of the eclipse of B.C. 430 August 3, with that of PERICLES is now happily removed by my investigations; for I have found that the line of central eclipse passed much nearer to Athens than has been heretofore supposed.

My elements give

$$
\begin{array}{llll}
t = 21^h\ 44^m\ 38^s & & & \\
\alpha = \alpha' = & 126^\circ\ 53'\ 25''.3 & D = \ 925''.9 & \Delta\alpha = \ 1947''.1 \\
\delta = + & 20\ 14\ 19\ .7 & D' = \ 954\ .6 & \Delta\alpha' = \ 149\ .6 \\
\delta' = + & 19\ 23\ 47\ .3 & \pi = 3445\ .2 & \Delta\delta = -\ 642\ .3 \\
 & & & \Delta\delta' = -\ \ 35\ .2
\end{array}
$$

These give for central eclipse at noon:

$$\lambda = +42^\circ\ 37', \qquad \phi = +83^\circ\ 0'.$$

The line of central eclipse passes through the following points:

T	λ	ϕ
h m	° ′	° ′
23 0	—15 4	+49 54
23 4	17 0	47 49
23 8	19 47	45 43
23 12	22 54	43 20
23 16	27 19	40 27
23 18	30 54	38 32
23 19.5	—35 15	+36 20

The last position given denotes the point where the axis of the moon's shadow leaves the earth.

The central line therefore passes very near to the Hellespont, or about 250 miles from Athens; while Hansen's tables would throw the shadow a long distance beyond the sea of Azov, at least 1000 miles from Athens. The local mean time of greatest eclipse at Athens was $6^h\ 2^m$, or $5^h\ 56^m$ apparent time; and since sunset occurred at $7^h\ 6^m$ apparent time, it follows that the greatest phase occurred $1^h\ 10^m$ before sunset. I also find the greatest magnitude of the eclipse at Athens was 0.9221 of the sun's diameter, or 11.06 digits on the sun's northern limb. By means of such an obscuration the planets and the brighter stars would most certainly be visible. There can therefore no longer be any doubt that this is the eclipse referred to by the historian.

27. Eclipse number 9 is the one which is supposed to have taken place while Xerxes was on the march from Sardis to Abydos at the beginning of the Persian war. The traditions concerning it I take from Newcomb's *Researches*, page 31.

"From Herodotus, VII, 37:

'When the army, having come out of their winter quarters, in the opening of the spring, fully equipped, set out from Sardis, for the purpose of marching to Abydos; and when they had begun their march, the sun, leaving his seat in the heavens, was concealed from view, and night, instead of day came on, though the weather was not cloudy, but was exceedingly clear.'

"From Aristides, Scholiast., ed. Frommel, p. 222 (quoted from Zech, p. 39):

'As the king was going against Greece, and had come into the region of the Hellespont, there happened an eclipse of the sun in the east: for it portended to him his defeat, that the sun was eclipsed in the region of its rising, since Xerxes was also marching from the east.'"

The natural inference from the narrative by Herodotus is, that the sun was totally eclipsed at Sardis. But it is evident that an eclipse of the sun which was total at Sardis, must have been very nearly total at Athens, which is only about 250 miles distant: and as there are no traditions of its having been seen in Greece, it is obvious that the phenomenon must have been much less striking than the account by Herodotus would lead us to suppose. On the other hand the account by Aristides only shows that an eclipse occurred in the early morning, while the sun was still in the "region of its rising"; and is fully satisfied by any eclipse of the sun, however small it might be.

It has therefore been a matter of much difficulty to astronomers, to explain the phenomenon by any solar eclipse at that time; and hence it has been supposed by some, that the date of the Persian expedition has not been correctly given. This supposition is rendered somewhat plausible from the fact that a large annular eclipse must have been visible at Sardis on February 16, in the year B.C. 477. But it occurred a little after noon; and hence it would be wholly incompatible with the narrative of Aristides, who says it took place in the east, a fact which is also obscurely indicated by the account of Herodotus.

I have therefore calculated the eclipse of April 19, B.C. 480, and have obtained the following elements:

$$
\begin{array}{llll}
t = 13^h\ 10^m\ 41^s & & & \\
\alpha = \alpha' = & 21^\circ\ 3'\ 51''.0 & D = 16'\ 30''.8 & h\alpha = 2166''.5 \\
\phantom{\alpha = {}}\delta = & +\ 9\ 17\ 16\ .1 & D' = 15\ 18\ .9 & h\alpha' = 134\ .6 \\
\phantom{\alpha = {}}\delta' = & +\ 8\ 59\ 40\ .4 & \pi = 60\ 36\ .2 & h\delta = +\ 646\ .1 \\
 & & & h\delta' = +\ \ 53\ .8
\end{array}
$$

These elements give for central eclipse at noon

$$\lambda = -84^\circ\ 46', \qquad \phi = +25^\circ\ 52'.$$

And the line of central and total eclipse passes through the points given by the following coordinates:

T	λ	ϕ
h m	° ′	° ′
11 21	—21 26	0 0
11 40	49 50	+ 7 25
12 0	60 32	12 25
12 20	68 15	16 10
12 40	74 53	20 34
13 0	81 18	24 6
13 20	—88 1	+27 22

The eclipse was partial at Sardis. I find the time of greatest eclipse at Sardis was $12^h\ 9^m.2$ mean time at Washington, which corresponds to a local mean time of $7^h\ 9^m$ in the morning. The magnitude of the eclipse at Sardis was 0.09 of the sun's diameter, or 1.08 digits on the sun's lower-limb. The account of the eclipse by Aristides is therefore fully confirmed by this computation.

The eclipse at Susa was much larger, amounting to 1.61 digits at $8^h\ 12^m$ in the morning; but at Athens it was very much smaller, amounting to only 0.0126 of the sun's diameter, or 0.15 of a digit, a quantity much too small to be noticed without the aid of a telescope.

28. Eclipses number 10 and 11 have been computed for the purpose of explaining a phenomenon recorded by Xenophon, in the third book of his *Anabasis*. He mentions a deserted city of considerable size, called Larissa: and which has been identified by the great Assyrian ruins of Nineveh or Mosul. He also states that the city was formerly inhabited by the Medes, and that when the Persians obtained the empire from the Medes, their king besieged it, but could not in any way take it. A gloom [or cloud], however, covered the sun, and caused it to disappear completely, till [i.e. to such a degree that] the inhabitants left (the city), and so it was taken.

Professors Airy and Hansen have explained the disappearance of the sun at Larissa by means of a total eclipse, which took place late in the afternoon of May 19, B.C. 556. I find, however, that the sun set totally eclipsed in longitude 37° 16′ east of Greenwich, and in latitude 28° 32′ north, at $6^h\ 17^m$ apparent time at Larissa, which was only about ten minutes before sunset at that place. And since the longitude of Larissa is 43° 20′ east, and the latitude is 36° 6′ north, it follows that the sun set at Larissa partially eclipsed.

But the eclipse which happened ten years later, namely, in B.C. 546 October 23, seems to explain the phenomenon much better; since it occurred about the middle of the afternoon, and was also much larger at Larissa.

For this eclipse I find

$$
\begin{array}{llll}
t = 17^h\,33^m\,45^s & & & \\
\alpha = \alpha' = & 20^\circ\ 5'\ 44''.9 & D = 16'\ 44''.4 & \Delta\alpha = 34'\ 28''.4 \\
\delta = & -\ 8\ 30\ 52\ .9 & D' = 16\ 16\ .2 & \Delta\alpha' = 2\ 23\ .0 \\
\delta' = & -\ 9\ 24\ 31\ .9 & \pi = 61\ 25\ .9 & \Delta\delta = -17\ 24\ .8 \\
 & & & \Delta\delta' = -\ 0\ 56\ .8
\end{array}
$$

These elements give for central eclipse at noon,

$$\lambda = -16^\circ\ 31', \qquad \phi = +51^\circ\ 28'.$$

And the line of central and total eclipse passes through the points given by by the following coordinates:

T	λ	ϕ
h m	° ′	° ′
17 40	—19 55	+48 15
17 50	23 40	44 0
18 0	27 9	40 12
18 10	30 22	36 45
18 20	33 31	33 40
18 30	36 45	30 50
18 40	—40 16	+28 16

The path of the total eclipse is illustrated by the map to which I have already called attention.

The local mean time of greatest eclipse at Larissa, was $2^h\,31^m$ p.m.; and the magnitude of the eclipse at that place was 0.8657 of the sun's diameter: or 10.4 digits on the sun's southern limb. It was therefore a very large eclipse at Larissa, and might have occasioned the gloom which frightened its defenders.

29. Eclipses number 12, 13 and 14, have each in turn been supposed to be the eclipse of Thales. I have already observed that Mr. Baily, for historical and astronomical reasons, was led to believe that the eclipse of 609 Sept. 30 was indeed the correct one; and that Professor Airy rejected it because it was apparently incompatible with the eclipse of Agathocles. But I have found the reverse to be the case; and that the eclipse of B.C. 584 May 28, is really the incompatible one. The reason assigned by Professor Newcomb for doubting the reality of the occurrence of any eclipse at the time of the battle, if it took place in B.C. 584 would not apply to the circumstances of the battle if it took place in B.C. 609; because the latter took place almost at the instant of noon, while the former took place at sunset when darkness was otherwise close at hand, and might have been prematurely hastened by the presence of a heavy bank of clouds in the vicinity of the sun at that time. But Hansen, in his *Darlegung*, has urged other reasons against the eclipse of B.C. 609 being the one described by Herodotus. For, according to Herodotus, the eclipse was predicted by Thales; and Thales is supposed to have been born in B.C. 640; so that he was really a young man at the time of the eclipse, being only about thirty years old; and Hansen was inclined to doubt his ability to predict an eclipse at that youthful age. However that may be, I have adopted it for the true date of the eclipse, and have used it in connection with the eclipses of Pericles and Agathocles for the rectification of the elements of the moon's motion.

The locality at which the battle was fought is also of some importance in this connection. Hansen assumes that it was near to Boghazkoei (or Boghaz Kieui as it is given in English maps of that country), longitude 34° 35′ east, and latitude 40° 1′ north; "in whose vicinity, lately monuments cut in rocks have been found, which clearly point to the war of the Lydians and Medians, to the battle at which time this eclipse took place, and to the events of the peace hereupon made." It will be seen, by reference to the map, that the northern limit of totality in the eclipse of B.C. 609 Sept. 30, just covers Boghazkoei; so that the condition of totality at that place is satisfied. But I was surprised to find that the same elements of the moon's motion, when applied to the computation of the eclipse of B.C. 602 May 18, gave a zone of totality which satisfied all the conditions of the eclipse-battle equally well, if not better than the eclipse of 609. In fact, the eclipse of B.C. 602 May 18, was one of the most remarkable ones that can possibly take place; not only on account of the great breadth of the shadow, but also for the length of time during which it was total. The shadow in its course across Asia Minor was circular, and had a diameter of more than 200 miles; and the duration of totality along the central line was no less than $7^m\,4^s$. It also passed very nearly centrally over Boghazkoei; and the central line followed the river Halys a distance of no less than 200 miles.

It therefore follows that both the two eclipses B.C. 609 Sept. 30, and B.C. 602 May 18, satisfy equally well the astronomical conditions of the problem. They both passed over the same locality within ten minutes of the same time of day; and their general astronomical features were the same in every respect except in the duration of totality. But this last feature would render the eclipse of B.C. 602 May 18 far more impressive; since, according to the present computation, the totality of the former could not have exceeded half a minute at Boghazkoei, while for the latter it must have continued nearly fifteen times as long. Besides, Hansen's objections to the eclipse of 609 being the one predicted by Thales, on account of his youthful age, would have much less force when applied to an eclipse which happened seven years later. It would therefore seem that the eclipse of B.C. 602 May 18 was rather the more probable of the two; but the decision of the question must be determined by means of historical rather than astronomical considerations.

For the eclipse of B.C. 602 May 18, we have

$$
\begin{array}{llll}
t = 16^h\,8^m\,0^s & & & \\
\alpha = \alpha' = & 46^\circ\ 40'\ 21''.0 & D = 16'\ 57''.0 & \Delta\alpha = 37'\ 15''.3 \\
\delta = & +18\ 12\ 29\ .0 & D' = 15\ 45\ .5 & \Delta\alpha' = 2\ 24\ .1 \\
\delta' = & +17\ 46\ 26\ .8 & \pi = 61\ 11\ .7 & \Delta\delta = +13\ 44\ .4 \\
 & & & \Delta\delta' = +\ 0\ 39\ .4
\end{array}
$$

For the place of central eclipse at noon we have

$$\lambda = -38^\circ\ 45', \qquad \phi = +43^\circ\ 0'.$$

And the line of central and total eclipse passes through the points given by the following coordinates:

T	λ	ϕ	*T*	λ	ϕ
h m	° ′	° ′	h m	° ′	° ′
15 20	−20 35	+30 26	15 52	−32 1	+39 8
15 28	23 20	32 15	16 0	35 15	41 6
15 36	26 7	34 58	16 8	38 15	43 0
15 44	−29 0	+37 6	16 16	−42 35	+44 52

For the eclipse of B.C. 609 Sept. 30 we have

$$t = 16^h\ 29^m\ 24^s$$

$$\begin{array}{llll}
\alpha = \alpha' = & 179^\circ\ 57'\ \ 9''.0 & D = 16'\ 38''.8 & \Delta\alpha = \ \ 35'\ 50''.2 \\
\delta = & +\ \ 0\ \ 40\ \ 19\ .4 & D' = 16\ \ 11\ .3 & \Delta\alpha' = \ \ \ 2\ \ 17\ .8 \\
\delta' = & +\ \ 0\ \ \ 1\ \ 35\ .6 & \pi = 61\ \ \ 5\ .4 & \Delta\delta = -12\ \ \ 1\ .5 \\
 & & & \Delta\delta' = -\ \ 1\ \ \ 0\ .7
\end{array}$$

And for the place of central eclipse at noon we have

$$\lambda = -33^\circ\ 59', \qquad \phi = +\ 39^\circ\ 22'.$$

The line of central eclipse passes through the points given by the following coordinates:

T	λ	ϕ	*T*	λ	ϕ
h m	° ′	° ′	h m	° ′	° ′
16 20	−29 38	+41 30	16 40	−38 13	+37 3
16 24	31 30	40 35	16 44	39 46	36 11
16 28	33 17	39 41	16 48	41 17	35 20
16 32	34 59	38 18	16 52	42 46	34 30
16 36	−36 38	+37 55	16 56	−44 15	+33 40

30. The record of eclipse number 15 was discovered on the Assyrian tablets in the British Museum. It occurred B.C. 762 June 15, and for this date I find the following elements

$$t = 17^h\ 14^m\ 7^s$$

$$\begin{array}{llll}
\alpha = \alpha' = & \ \ 73^\circ\ 17'\ 49''.7 & D = 16'\ 30''.9 & \Delta\alpha = \ \ 40'\ 28''.9 \\
\delta = & +23\ \ 10\ \ 47\ .8 & D' = 15\ \ 46\ .1 & \Delta\alpha' = \ \ \ 2\ \ 33\ .9 \\
\delta' = & +22\ \ 54\ \ 10\ .6 & \pi = 60\ \ 36\ .3 & \Delta\delta = +\ \ 1\ \ \ 1\ .5 \\
 & & & \Delta\delta' = +\ \ 0\ \ 16\ .6
\end{array}$$

These elements give for central eclipse at noon

$$\lambda = -22^\circ\ 41', \qquad \phi = +38^\circ\ 49'.$$

And the path of central eclipse is given by means of the following coordinates:

T	λ	ϕ	*T*	λ	ϕ
h m	° ′	° ′	h m	° ′	° ′
16 50	−11 26	+37 45	17 40	−34 21	+38 13
17 0	16 0	38 23	17 50	39 7	37 28
17 10	20 32	38 45	18 0	41 1	36 24
17 20	25 5	38 50	18 10	−49 16	+34 59
17 30	−29 41	+38 40			

The track of the eclipse is shown on the map, from which it is seen that the shadow passed almost centrally over Nineveh, at $18^h\ 0^m$ mean time at Washington; or, at two o'clock in the afternoon at Nineveh.

31. Eclipse number 16, the earliest of the series, has been computed because it took place during the last year of the Trojan war; and it was thought that possibly it might explain the singular darkness that occurred during one of the great battles mentioned by HOMER, provided its path was such as to take it through Asia Minor. This proved to be the case; but I was greatly surprised to find that the moon's shadow passed directly over the Hellespont, and consequently must have enveloped the whole Trojan territory in darkness. On account of this happy coincidence of time and place. I have ventured to designate this as the *eclipse* of HOMER; although I am not aware that any one has ever attempted to explain the darkness of that occasion by means of a total solar eclipse. It occurred B.C. 1184 August 28; and for this date I find the following elements:

$$t = 18^h\ 40^m\ 17^s$$

$$\begin{array}{llll}
\alpha = \alpha' = & 115^\circ\ 59'\ 29''.5 & D = 16'\ 42''.4 & \Delta\alpha = \ \ 38'\ \ 7''.9 \\
\delta = & +11\ \ 30\ \ 12\ .7 & D' = 16\ \ \ 3\ .8 & \Delta\alpha' = \ \ \ 2\ \ 23\ .9 \\
\delta' = & +13\ \ 53\ \ 26\ .3 & \pi = 61\ \ 18\ .5 & \Delta\delta = -9\ \ 21\ .0 \\
 & & & \Delta\delta' = -0\ \ 49\ .7
\end{array}$$

These give for central eclipse at noon

$$\lambda = -3^\circ\ 15', \qquad \phi = +50^\circ\ 45'.$$

The line of central eclipse passes through points given by the following coordinates:

T	λ	ϕ	*T*	λ	ϕ
h m	° ′	° ′	h m	° ′	° ′
18 0	+28 14	+55 11	19 0	−14 7	+47 6
18 10	18 40	54 39	19 10	19 6	45 0
18 20	10 28	53 40	19 20	23 54	42 45
18 30	+ 3 19	52 23	19 30	28 40	40 21
18 40	− 3 4	50 48	19 40	33 37	37 46
18 50	− 8 49	+49 2	19 50	38 58	34 56
			20 0	−45 15	+31 45

HOMER's description of the event is found in the seventeenth book of the *Iliad*, of which POPE gives the following spirited translation:

> "In one thick darkness all the fight was lost
> The sun, the moon, and all th' ethereal host,
> Seem'd as extinct, day ravish'd from their eyes
> And all heaven's splendors blotted from the skies."

Had the poet been attempting to describe a total eclipse of the sun as it would appear amidst the dust and turmoil of a battle-field, his description could hardly have been more accurate. It is true he may have somewhat exaggerated some of the circumstances of the occasion in order the better to immortalize his hero; but on the whole the description is so truly natural that we cannot on that account withhold belief in its reality. This eclipse I think may therefore be considered as the earliest one recorded in Grecian history. It precedes the Nineveh eclipse, which has heretofore been regarded as the most ancient eclipse on record, by more than four hundred years; and on that account is doubly valuable as an important epoch in both history and science. It passed the battle-field at twenty-one minutes past two o'clock in the afternoon; and marks the turning point in the fortunes of Troy; and also constitutes a fitting termination to the already waning glories of the heroic age.

It will be seen by the map that this eclipse was unusually large, and must have swept over nearly the whole of the territory of Asia Minor, south of a line drawn from the straits of the Bosphorus to the northern point of the gulf of Issus. It was therefore a very remarkable eclipse.

32. We see from this discussion, that the secular variations of the moon's orbit, which I have obtained by means of analysis, when taken in connection with corrections of the mean motions of the perigee and node, which have been

obtained by means of only three of the eclipses, give elements of the moon's orbit which very perfectly represent the whole series of eclipses. The eclipses employed for correcting the elements embrace a period of only 300 years; while the whole series of eclipses which have been discussed extend over a period of more than 3000 years; and appear to be equally well represented with those which were used in order to obtain the corrections. This perfect agreement between theory and observation when extended over so long a period of time seems to justify the conclusion that the elements of the moon's motion which have been employed in the discussion, are essentially correct; and may therefore be applied to all past and future ages, without differing widely from the truth, in the representation of observed phenomena.

33. It remains now to show the effect of these corrections on the periodic inequalities which affect the moon's motion. I shall not enter into the general discussion of this problem, but shall confine my attention to the three principal equations of the longitude, in which the longitude of the moon's perigee enters as a term of the argument. These three terms are, the first and second terms of the equation of the center, and the evection. I find the correction of the moon's longitude, Δv, arising from a correction to the longitude of the perigee, $\Delta\omega$, will be given by the following equation, in which nt, $n't$ and ω, denote respectively the mean longitudes of the moon and sun and the moon's perigee.

$$(42)\left\{\begin{aligned}\frac{\Delta v}{\Delta\omega} = &-0.10976\cos(nt-\omega) - 0.00746\cos 2(nt-\omega)\\ &+0.02223\cos(nt-2n't+\omega)\end{aligned}\right.$$

We have already found the correction to the mean motion of the perigee to be $+0''.7500$ in a Julian year, and the correction of the secular equation of the perigee to be $+52''.865$ in a Julian century. We shall therefore have at any time t, from the epoch

$$(43)\qquad \Delta\omega = 0''.7500\cdot t + 0''.0052865\cdot t^2,$$

t denoting Julian years. With this formula I have computed the corrections to Hansen's longitude of the perigee at intervals of ten years for a period of two hundred years before and after the epoch, as in the following table.

Table Showing Corrections to Hansen's Longitude of Perigee.

t	$\Delta\omega$	t	$\Delta\omega$
	″		″
+ 0	0.00	0	0.00
10	+ 8.03	—10	— 6.97
20	17.11	20	13.89
30	27.26	30	17.74
40	38.46	40	21.54
50	50.72	50	24.28
60	64.03	60	25.97
+ 70	+ 78.40	—70	—26.60
+ 80	+ 93.83	— 80	— 26.17
90	110.32	90	24.68
100	127.86	100	22.14
110	146.47	110	18.53
120	166.12	120	13.88
130	186.84	130	8.16
140	208.6	140	— 1.04
150	231.4	150	+ 6.4
160	255.3	160	15.3
170	280.3	170	25.3
180	306.3	180	36.3
190	333.3	190	48.3
+200	+361.5	—200	+61.5

The epoch of Hansen's tables is 1800 Jan. 0.0. According to equation (42) the correction to the moon's longitude is included within the limits $0''$ and $\pm\frac{1}{7}\cdot\Delta\omega$. The elements being supposed correct at the epoch, the error in the longitude, arising from this cause, in 1820 would amount to something over $2''$; in 1850 it would be something over $7''$; while in 1890, the correction would amount to $16''$. There would, therefore, be a gradually widening distance between computation and observation, which would be apparently due to one or more inequalities of long period in the moon's motion; although they were in reality due to errors in the mean and secular motions of the perigee. The deviations during the years antecedent to the epoch would be much smaller, on account of the much slower change in the value of $\Delta\omega$ during the first two centuries. It therefore seems to me that the errors in the moon's longitude arising from the errors in the longitude of the perigee, taken in connection with the fact that Hansen's coefficient of the secular variation of the moon's longitude is too great by something more than $4''$, is sufficient to explain the fact of *apparent* inequalities of long period in the moon's motion, even though such inequalities have no real existence in nature. The complete establishment of this proposition by means of a rigorous comparison with the accurate observations of the moon which have been made during last 150 years is too great a work for private enterprise; and I have restricted my comparison to the records of solar eclipses which have come down to us through the ages, and find an entirely satisfactory agreement between calculation and observation. This agreement also tends to prove the constancy of the duration of a day; and to dispose of the hypothesis of the tidal retardation of the earth's rotation, which has recently come into prominence.

Cleveland, O. 1890 *May* 15.

Note. The map illustrating the eclipses which have been discussed, has been prepared by my son Edward A.; and the shaded ovals approximately represent the *size*, *form*, and *position* of the shadow when at the particular points where they are located. For the two Thales(?) eclipses they designate the place of central eclipse at noon; which is also the case with the eastern oval in the eclipse of Agathocles.

CONTENTS.

On the Secular and Long-Period Inequalities in the Moon's Motion, by Prof. John N. Stockwell.

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THE THICKNESS OF *SATURN'S* RING.

By A. HALL.

A knowledge of the mass of the Ring of *Saturn* would be interesting, since the inner satellites of this planet move nearly in the plane of the Ring, and their motions may be sensibly influenced by the action of this mass. If we suppose the Ring to be a thin cylindrical body, of uniform thickness and density, a particle moving in its equatorial plane would have its differential equation of motion of the form:

$$d\varphi = \frac{\pm dz}{\sqrt{a + a_1 z + a_2 z^2 + a_3 z^3 + a_5 z^5 + a_7 z^7 + \ldots\ldots}}$$

in which $z = \frac{1}{r}$; and φ and r are the polar coordinates in the equatorial plane. If in this equation we neglect powers of z above the second, since $a_2 = -1$, we shall have the trigonometrical integral which gives the common elliptic motion; and the action of the Ring will be the same as though its mass were concentrated at the center. But if higher powers of z be retained the motion becomes more complicated, since we shall have elliptic and hyperelliptic integrals. A determination of the thickness of the Ring will not of course furnish a knowledge of its mass, since the density remains unknown, but such a determination may be useful as a guide in making an estimate.

So far as I know the only determinations of the thickness of the Ring by observation are the following:

No.	Author	Thickness	Eng. Miles
		″	
1	DUSEJOUR	0.221	958
2	W. HERSCHEL	0.2	856
3	SCHROETER	0.126	539
4	W. C. and G. P. BOND	<0.01	< 43

1. This is the value of the thickness generally given as found by DUSEJOUR, and is taken from his *Traité Analytique*, Tome II, p. 127. Paris, 1789. It is the result of a discussion of the disappearances and reappearances of the Ring observed before 1789; and is hardly more than a hypothetical thickness introduced for the purpose of satisfying these observations. In fact, DUSEJOUR says himself that we must consider the real thickness of the Ring as unknown.

2. HERSCHEL'S determination was made in 1789, soon after his discovery of the two inner satellites. It is an estimate made by comparing the thickness of the Ring with the apparent diameters of the various satellites (*Philosophical Transactions*, Vol. LXXX, pp. 6 and 7. London, 1790).

3. SCHROETER'S value was found from measurements of the width of the trace of the Ring on the ball of the planet in 1803, June 25, *Kronographische Fragmente*, pp. 157 and 211, Göttingen, 1808. These observations appear to have been made with great care.

4. The last determination was made at the Harvard College Observatory in September, 1848, *Annals*, Vol. II, pp. 121 and 122. The method followed was to compare the amount of light received from the surface of the Ring, a short time before its disappearance, with the light received from the edge of the Ring. Very little detail of the observations is given, and one cannot judge well of the accuracy of this result, but the method appears to be well worth another trial.

Let a_1 be the radius of the outer edge of the Ring, and a_2 the radius of the inner edge; if we assume the Ring to be circular we shall have

$$\textit{area elliptical ring} = \pi \sin\theta\,(a_1^2 - a_2^2),$$

where θ is the elevation of the observer above the plane of the Ring. The edge of the Ring will appear as a straight line $= 2a_1$; and, if d be the thickness, the ratio of the surfaces near the time of disappearance will be

$$\frac{\pi \sin\theta\,(a_1^2 - a_2^2) + 2a_1 d - s}{2a_1 d} = A,$$

s being the part of the surface of the Ring hidden by the ball of the planet. s will be an area bounded by three ellipses, for which an exact integral can be found, and the chief difficulty of the computation will be in determining the value of this integral for the rather complicated limits of integration. When the value of the ratio A has been found by observation, we can find d from the above simple equation.

The next disappearance of the Ring of *Saturn* will be 1891 Sept. 22, and it will reappear on Oct. 30 of the same year. Unfortunately at that time the planet will be very near the sun, although perhaps, some observations may be made at the reappearance. The elevation of the earth above the plane of the Ring will be small again on May 20, 1892, and then *Saturn* will be more favorably situated for observation. Perhaps with the improved methods of photometry and photography some more certain results may be obtained for the thickness of the Ring.

Washington, D.C., 1890 *June* 25.

OBSERVATIONS OF VARIABLE STARS OF THE *ALGOL*-TYPE.

By PAUL S. YENDELL.

The observations whose results are here detailed are in continuation of the line of work, part of which has already been published in this Journal, Vol. IX, p. 81. As there mentioned, an effort has been made to secure observations of all the available minima of all the objects of this class, and it is much regretted that the great prevalence of unfavorable weather during the past year has so seriously interfered with this line of work; of one star, *λ Tauri*, useful observation has been entirely prevented by weather and illness, the few observations secured on three evenings being of entirely tentative character, and in no way worth publishing.

Minima have been observed as follows: of *Algol*, four; of *U Cephei*, two; of *R Canis Majoris*, three; and of *S Cancri*, two, with observations on three evenings from which minima have been deduced. The reductions have been made on the same plan as those published in the former paper, except that in the case of *R Canis Majoris*, no standard light-curve has been published, and my own observations do not afford sufficient material for the construction of such.

The results of my observations of PAUL's new variable of this class, *S Antliae*, have already been published in this Journal, and on that account, are not included here.

Algol.

The following four minima of *Algol* have been deduced from a series of naked-eye observations; the mean light-curve employed is that of SCHÖNFELD, published in the *Jahresbericht des Mannheimer Vereins für Naturkunde*, no. 36, p. 87.

1889 Nov. 15; fifteen observations, from $5^h\ 45^m$ to $12^h\ 15^m$ C.M.T.

Time of minimum by single curve, $11^h\ 18^m.5$, wt. 5.

Time of minimum by mean curve, $10^h\ 57^m.3$.

Time of minimum by equal brightness,

	Before	After	Middle
M	h m	h m	h m
3.3	10 34.5	12 0.5	11 17.5
3.4	11 0.5	11 41.5	11 19.5
Mean of middle times			11 18.5

1889 Nov. 18; nineteen observations, from $5^h\ 45^m$ to $9^h\ 53^m$.

Time of minimum by single curve, $8^h\ 28^m.5$, wt. 5.

Time of minimum by mean curve, $8^h\ 27^m.3$.

Time of minimum by equal brightness,

	Before	After	Middle
M	h m	h m	h m
3.3	7 13	9 33	8 23
3.4	7 30	9 20	8 25
3.5	8 10	8 44	8 27
Mean of middle times			8 25

1889 Dec. 11; seven observations, from $5^h\ 13^m$ to $7^h\ 33^m$.

Time of minimum by single curve, $6^h\ 48^m$, wt. 1.

Time of minimum by mean curve, $6^h\ 16^m$.

Time of minimum by equal brightness is not given, for want of sufficient observations after minimum.

1890 Feb. 12; six observations, from $6^h\ 50^m$ to $9^h\ 50^m$.

Time of minimum by single curve, $9^h\ 19^m$, wt. 3.

Time of minimum by mean curve, $8^h\ 31^m$.

Time of minimum by equal brightness,

	Before	After	Middle
M	h m	h m	h m
3.4	8 42	9 40	9 11

U Cephei.

Two minima have been observed. The mean light-curve employed is that of CHANDLER (autumn).

1889 Nov. 18; fourteen observations, from $6^h\ 10^m$ to $9^h\ 35^m$ C.M.T.

Time of minimum by single curve, $7^h\ 35^m.5$, wt. 5.

Time of minimum by mean curve, $7^h\ 42^m.9$.

Time of minimum by equal brightness,

	Before	After	Middle
M	h m	h m	h m
8.9	6 53.5	8 57.5	7 55.5
9.0	7 2.5	8 45.5	7 54.0
9.1	7 13.5	8 20.5	7 47.0
9.2	7 28.5	7 39.5	7 34.0
Mean of middle times			7 47.6

1889 Nov. 28; fifteen observations, from $5^h\ 40^m$ to $9^h\ 17^m$.

Time of minimum by single curve, $6^h\ 44^m.5$.

Time of minimum by mean curve, $7^h\ 3^m.0$.

Time of minimum by equal brightness,

M	Before h m	After h m	Middle h m
8.9	6 10.5	8 22.5	7 16.5
9.0	6 15.5	8 6.5	7 11.0
9.1	6 20.5	7 37.5	6 59.0
Mean of middle times			7 8.8

R Canis Majoris.

Three minima have been observed, as follows:

1890 Jan. 16; seven observations, from 7h 45m to 9h 33m C.M.T.

Time of minimum by single curve, 8h 7m, wt. 3.

Time of minimum by equal brightness.

M	Before h m	After h m	Middle h m
6.2	7 48	8 30	8 9
6.3	7 55	8 20	8 7.5
Mean of middle brightness			8 8.25

1890 March 8; fifteen observations, from 8h 5m to 11h 51m.

Time of minimum by single curve, 10h 50m, wt. 4.

Time of minimum by equal brightness,

M	Before h m	After h m	Middle h m
6.7	10 3	11 30	10 46.5
6.8	10 18	11 19	10 48.5
6.9	10 25	11 3	10 44.0
Mean of middle brightness			10 46.3

1890 April 18; three observations, from 7h 45m to 8h 30m.

Time of minimum by single curve, 8h 6m, wt. 2.

Time of minimum by equal brightness.

M	Before h m	After h m	Middle h m
6.8	7 56	8 17	8 10.5

S Cancri.

Two minima of *S Cancri* have been observed. The light-scale and mean light-curve used in the reductions are those of Schönfeld, published in his monograph on the star in the *Jahresbericht des Mannheimer Vereins*, no. 38, p. 63. The reduction by equal lights has not been applied to this star, on account of the peculiar nature of its light-curve. All the observations of *S* were made with the 4¼-inch refractor. On three evenings, observations have been made from which minima could be inferred. The observed minima are as follows:

1890 Feb. 15: thirteen observations, from 7h 15m to 13h 5m C.M.T.

Time of minimum by single light-curve, 12h 11m, wt. 1.

Time of minimum by mean light-curve 12h 8m.

Dorchester, 1890 *May* 21.

1890 Apr. 13: twelve observations, from 7h 15m to 11h 30m.

Time of minimum by single curve, 10h 12m.5, wt. 1.

Time of minimum by mean curve, 9h 55m.9.

From observations made when the actual minima were not observed, I deduce the following epochs of minima.

	h m	L	W
1890 Feb. 6,	7 30	11.4	1
	55	17.75	2
	8 35	16.15	1
	9 5	17.00	4
	40	17.00	4
	10 10	18.25	4

Inferred minimum Feb. 6, 0h 10m.0

	h m	L	W
1890 May 2,	8 30	7.65	4
	9 3	3.80	2
	15	2.80	2
	32	2.80	3

Inferred minimum May 2, 9h 45m.0

	h m	L	W
1890 May 12,	8 25	17.25	4
	9 0	18.75	4
	35	19.25	4

Inferred minimum May 11, 21h 22m.6

Recapitulation.

Algol.

	Single Curve h m	Wt.	Mean Curve h m	Equal Br.
1889 Nov. 15,	11 18.5	5	10 57.3	11 18.5
18,	8 28.5	5	8 27.3	8 25.0
Dec. 11,	6 48.0	1	6 46.0	
1890 Feb. 12,	9 19.0	3	8 31.0	9 11.0

U Cephei.

	Single Curve	Wt.	Mean Curve	Equal Br.
1889 Nov. 18,	7 35.5	5	7 12.9	7 17.6
28,	6 14.5	4	7 3.0	7 8.8

R Canis Majoris.

	Single Curve	Wt.	Mean Curve	Equal Br.
1890 Jan. 16,	8 7.0	3		8 8.25
Mar. 8,	10 50.0	1		10 46.0
Apr. 18,	8 6.0	2		8 10.5

S Cancri.

	Single Curve	Wt.	Mean Curve	Equal Br.
1890 Feb. 15,	12 11.1	4	12 8.0	
Apr. 13,	10 12.5	4	9 55.9	
Feb. 6,		1½	0 10.0	
May 2,		1	9 15.0	
11,		½	21 22.6	

My observations of *Y Cygni*, made during the same autumn and winter, have already been published in this Journal, Vol. IX, p. 166.

NEW ASTEROID.

A planet of the twelfth magnitude was discovered July 15, by Mr. Charlois, at Nice, who gives the position:—

1890 July 15.5277 Greenw. M.T. $\alpha = 21^h\,22^m\,56^s.7$, $\delta = -13°\,39'\,32''$. Daily motion, −7m in α, and 5′ southward.

This, if new, is no. 291.

SUN-SPOT OBSERVATIONS,

MADE AT BRYN MAWR, PENN., WITH A 3-INCH REFRACTOR.

BY A. W. QUIMBY.

1890	Time	Grs.	Sps.	Fac. Grs.	Def.
Jan. 2	9	1	1	0	fair
3	9	1	1	0	good
4	9	1	1	0	fair
6	9	1	1	0	poor
8	9	0	0	0	poor
9	9	0	0	0	poor
10	10	0	0	0	bad
12	9	0	0	0	fair
13	9	0	0	0	poor
14	9	0	0	0	fair
15	2	0	0	0	bad
16	1	0	0	0	poor
17	9	0	0	1	fair
18	9	0	0	0	poor
19	9	2	21	0	good
21	1	2	10	1	fair
22	9	0	0	0	good
24	8	0	0	0	fair
25	10	0	0	0	bad
26	8	0	0	1	fair
27	8	0	0	1	fair
28	8	0	0	0	good
29	9	0	0	0	good
30	8	0	0	0	poor
31	1	0	0	0	poor
Feb. 1	1	0	0	0	bad
5	10	0	0	0	fair
6	11	0	0	0	fair
7	10	0	0	0	poor
9	8	0	0	0	poor
10	9	0	0	0	fair
11	11	0	0	0	fair
12	10	0	0	0	fair
13	9	0	0	0	good
14	8	0	0	0	poor
15	8	0	0	1	fair
16	8	0	0	0	fair
17	8	0	0	0	poor
18	8	0	0	0	fair
19	8	0	0	0	poor
20	2	0	0	0	poor
21	8	0	0	0	fair
22	8	0	0	0	fair
23	8	0	0	0	fair
26	4	0	0	0	good
27	2	0	0	0	poor
Mar. 2	9	0	0	0	fair
3	8	1	10	1	good
4	9	1	13	1	fair
5	9	1	6	0	fair
6	1	1	8	0	poor
7	9	1	11	0	fair
8	10	1	19	0	fair
Mar. 9	9	1	17	0	fair
10	8	1	6	0	poor
11	1	1	3	0	poor
12	9	1	3	0	fair
15	9	0	0	0	poor
16	7	0	0	0	good
17	7	0	0	0	fair
18	8	0	0	0	fair
19	4	0	0	0	poor
20	8	0	0	0	fair
21	4	0	0	0	poor
23	8	0	0	0	fair
24	7	0	0	0	poor
25	1	0	0	0	poor
26	7	0	0	0	fair
27	8	0	0	0	fair
28	1	0	0	0	poor
29	7	0	0	0	poor
30	8	0	0	0	fair
Apr. 1	10	0	0	0	good
2	9	0	0	0	good
3	9	0	0	0	good
4	4	0	0	0	fair
5	9	0	0	0	fair
6	8	0	0	0	fair
7	11	0	0	0	fair
8	7	0	0	0	fair
10	8	0	0	0	fair
11	8	0	0	0	fair
13	7	0	0	0	fair
14	7	0	0	0	fair
15	8	0	0	0	fair
16	8	0	0	0	fair
17	7	0	0	0	good
18	8	0	0	0	good
19	8	0	0	0	good
20	7	0	0	0	good
21	7	0	0	0	good
22	7	0	0	0	good
23	7	0	0	0	good
24	7	0	0	0	poor
25	6	0	0	0	fair
27	3	0	0	0	fair
28	7	0	0	0	fair
29	6	1	20	0	good
30	9	1	14	0	poor
May 1	7	1	6	0	poor
2	8	0	0	0	fair
3	8	0	0	1	good
4	9	0	0	0	bad
5	7	0	0	0	fair
7	7	0	0	0	fair
8	1	0	0	0	poor
May 9	7	2	26	0	fair
10	7	2	12	0	poor
11	2	2	9	0	poor
12	7	2	13	0	fair
13	7	2	. .	0	poor
14	1	0	0	0	fair
15	1	0	0	0	poor
16	7	0	0	0	poor
17	7	0	0	0	fair
18	7	2	9	3	good
19	11	2	0	0	fair
20	7	0	0	0	poor
21	8	1	1	1	fair
22	9	0	0	0	poor
23	7	0	0	0	poor
24	6	0	0	0	fair
25	1	0	0	0	poor
26	2	0	0	0	poor
27	9	0	0	0	poor
28	7	0	0	0	fair
29	7	0	0	0	fair
30	7	0	0	0	fair
31	7	0	0	0	fair
June 1	6	0	0	0	fair
2	7	0	0	0	fair
3	7	0	0	0	fair
4	7	0	6	0	fair
5	7	0	0	0	fair
6	7	1	10	0	fair
7	7	1	13	0	fair
8	7	1	8	0	fair
9	7	1	5	0	fair
10	7	0	0	0	fair
11	7	0	0	0	fair
12	7	0	0	0	fair
13	10	0	0	0	poor
14	7	0	0	1	fair
15	6	0	0	0	poor
16	7	0	0	0	poor
17	7	0	0	0	poor
18	6	0	0	0	poor
19	6	0	0	0	fair
20	2	0	0	0	poor
22	7	0	0	0	poor
23	7	0	0	0	poor
24	3	0	0	0	poor
25	7	0	0	0	fair
26	7	0	0	0	fair
27	7	0	0	0	fair
28	7	0	0	0	fair
29	7	0	0	0	fair
30	7	0	0	0	fair

NOTE. — On May 13 and 19, def. too poor to count spots.

SUN-SPOT OBSERVATIONS,

MADE AT THE HAVERFORD COLLEGE OBSERVATORY, WITH THE 8-INCH EQUATORIAL.

BY F. P. LEAVENWORTH.

1890	Time	Grs	Sps.	Fac Grs	Def. and Size
Jan. 3	11	1	1	0	poor
4	11	1	1	0	poor
6	11	1	1	0	bad
8	11	1	3	1	poor
9	10	1	2	0	bad
11	3	0	0	2	fair
12	3	2	3	4	fine : small
13	3	0	0	2	fair
14	11	0	0	0	poor
16	2	1	6	2	fair
17	10	1	8	3	good ; small
18	12	1	14	1	fine ; small
19	11	1	24	0	fine ; 2 large
21	1	1	6	1	good
22	11	1	2	1	poor
24	9	0	0	4	poor
25	2	0	0	0	bad
27	9	0	0	3	poor
28	10	0	0	3	poor
29	10	0	0	0	poor
30	11	1	4	1	good
Feb. 4	12	0	0	0	good
5	9	0	0	0	poor
6	12	0	0	0	fair
7	10	0	0	0	bad
9	9	0	0	4	fair
10	4	0	0	0	bad
11	2	0	0	0	fair
12	11	0	0	6	good
13	10	0	0	6	good
14	4	0	0	3	fair
15	10	0	0	7	fair
16	12	0	0	1	bad
17	10	0	0	3	fair
18	10	0	0	0	bad
20	4	0	0	0	poor
21	10	0	0	3	fair
22	11	0	0	0	poor
26	10	0	0	3	fair
Mar. 3	11	0	0	1	poor
4	11	1	5	0	good
5	12	1	5	0	fair ; large
6	4	1	5	0	fair ; large
7	12	1	5	0	poor ; large
8	10	1	10	0	poor ; 3 large
Mar. 9	5	1	18	0	fair : all sm.
10	10	1	9	0	bad
12	11	1	3	2	fair
13	2	1	3	2	fair
15	3	0	0	2	fair
16	10	0	0	3	fair
17	10	0	0	1	fair
18	10	0	0	3	good
20	12	0	0	1	fair
21	3	0	0	1	fair
23	9	0	0	0	poor
24	10	0	0	0	poor
26	9	0	0	2	fair
27	11	0	0	0	bad
28	12	0	0	2	good
29	10	0	0	0	poor
30	2	0	0	0	good
Apr. 1	10	0	0	1	good
2	10	0	0	0	fair
3	10	0	0	0	poor
4	3	0	0	0	fair
5	9	0	0	2	good
6	10	0	0	1	fair
7	10	0	0	1	fair
10	9	0	0	2	good
11	12	2	10	3	fine : small
12	10	2	18	3	fine : 1 large
13	10	2	11	3	fine ; small
14	10	0	0	1	good
15	11	0	0	0	bad
16	9	1	3	0	fair ; small
17	12	0	0	2	fair
18	5	0	0	0	fair
19	11	0	0	0	poor
20	12	0	0	0	fair
21	10	0	0	0	fair
22	10	0	0	0	poor
23	10	0	0	0	good
28	9	1	3	1	good : small
29	10	1	19	1	fine ; small
30	11	2	11	0	fair : small
May 1	12	1	2	2	good
2	11	0	0	0	poor
3	10	0	0	2	fair
5	10	0	0	1	fair
May 7	12	1	3	1	fair : small
8	2	1	8	1	good : small
9	10	1	22	2	fine : small
12	9	2	11	1	fair
13	12	1	10	1	fair
14	9	1	14	2	good : small
15	4	0	0	0	fair
17	10	3	9	3	fair : large
18	10	2	9	3	poor
19	10	3	6	2	fair
20	4	3	4	1	fair
21	9	2	3	1	poor
22	3	1	2	2	poor : small
23	4	1	3	1	fair
24	4	0	0	2	fair
27	4	1	3	3	bad ; small
28	9	0	0	1	fair
29	10	0	0	0	fair
31	10	0	0	1	poor
June 1	1	0	0	1	good
2	10	0	0	1	good
3	10	2	5	2	good : small
4	10	1	1	1	good
5	10	1	7	1	fair
6	10	1	11	0	poor : small
7	10	1	15	1	good : 1 lar.
8	10	1	4	1	bad : 1 large
9	9	1	6	1	poor : small
10	9	2	3	1	good
11	9	1	3	0	fair
12	12	0	0	1	fair
13	10	0	0	1	fair
14	9	1	4	3	good : small
18	10	0	0	1	good
19	10	0	0	0	fair
20	10	0	0	0	good
22	12	0	0	0	poor
23	9	1	1	1	good : small
24	5	0	0	1	good
25	10	0	0	1	good
26	10	0	0	1	fair
27	10	0	0	1	poor
28	11	0	0	0	fair
29	10	0	0	2	good
30	10	0	0	0	fair

EPHEMERIS OF COMET *a* 1890, (*BROOKS, March 19*).

BY W. W. CAMPBELL.

From an observation made by Mr. BARNARD, on July 2, the correction to my ephemeris of Comet *a* 1890 (*Astr. Jour.* no. 218), was found to be: $\cos\delta . \Delta\alpha = 1^s.5$, $\Delta\delta = +38''$. The following continuation of the ephemeris will therefore approximately represent the path of the comet.

Ephemeris for Greenwich Mean Midnight.

1890	App. α	App. δ	log r	log Δ	Br.
	h m s	° ′			
July 17	13 31 21	+52 18.0	0.2992	0.3162	1.96
19	29 57	51 45.3			
21	26 0	50 44.3	0.3024	0.3316	1.80
23	22 30	49 44.7			
25	19 23	48 46.7	0.3058	0.3465	1.65
27	16 37	47 50.8			
29	14 11	46 55.5	0.3093	0.3610	1.52
31	12 4	46 2.4			
Aug. 2	10 7	45 10.9	0.3131	0.3750	1.40
4	7 56	44 20.9			
6	6 57	43 32.6	0.3170	0.3883	1.29
8	5 40	42 45.9			
10	4 33	42 0.6	0.3211	0.4010	1.20
12	3 36	41 16.7			
14	2 46	40 34.3	0.3254	0.4130	1.11
16	2 4	39 53.3			
18	1 30	39 13.7	0.3297	0.4243	1.03
20	13 1 1	38 35.3			
22	0 39	37 58.2	0.3342	0.4350	0.96
24	0 21	37 22.4			
26	0 9	36 47.7	0.3388	0.4449	0.90
28	13 0 1	+36 13.8			
Aug. 30	12 59 56	+35 41.9	0.3435	0.4544	0.85
Sept. 1	59 56	35 10.6			
3	12 59 59	34 40.3	0.3483	0.4626	0.80
5	13 0 5	34 11.1			
7	0 13	33 42.8	0.3532	0.4705	0.75
9	0 25	33 15.7			
11	0 38	32 49.4	0.3581	0.4776	0.71
13	0 54	32 24.0			
15	1 12	31 59.4	0.3631	0.4841	0.67
17	1 31	31 35.9			
19	1 52	31 13.4	0.3681	0.4899	0.64
21	2 14	30 51.3			
23	2 38	30 30.2	0.3732	0.4950	0.61
25	3 2	30 10.0			
27	3 27	29 50.6	0.3783	0.4996	0.58
29	3 53	29 32.0			
Oct. 1	4 19	29 14.4	0.3835	0.5034	0.56
3	4 46	28 57.4			
5	5 13	28 40.8	0.3887	0.5067	0.54
7	5 40	28 25.2			
9	6 7	28 10.4	0.3938	0.5093	0.52
11	6 34	27 56.3			
13	13 7 0	+27 43.0	0.3990	0.5113	0.50

Lick Observatory, Mt. Hamilton, 1890 *July* 2.

SOLAR OBSERVATIONS AT SHATTUCK OBSERVATORY, JANUARY TO JULY 1890.

By EDWIN B. FROST.

I. Observations of Spots.

1890	E.S.C.T.	No. Gps.	No. of Spots	No. new Groups	No. new Spots.	No. Gps Faculae	Sky
	h m						
Jan. 2	10 20	1	1	0	0	0	K
3	9 0	1	1	0	0	0	K
7	14 0	0	0	0	0	0	K
9	12 45	1	2	1	2	0	C
12	15 0	0	0	0	0	0	C
14	14 0	0	0	0	0	0	C
17	12 20	1	2	1	2	1	C
18	12 15	1	5	0	4	–	HC
21	13 35	1	4	0	0	1	C
22	13 30	1	1	0	0	1	C
24	12 30	0	0	0	0	2	C
25	14 0	0	0	0	0	–	KK
26	12 30	0	0	0	0	3	CK
27	15 30	0	0	0	0	1	C
28	12 15	0	0	0	0	2	C
29	14 0	0	0	0	0	0	C
Feb. 3	14 0	0	0	0	0	3	K
5	14 0	0	0	0	0	2	C
6	11 10	0	0	0	0	1	C
7	11 15	0	0	0	0	2	K
9	11 45	0	0	0	0	1	C
Feb. 10	12 15	0	0	0	0	2	CH
11	13 55	0	0	0	0	3	CK
12	11 20	0	0	0	0	0	C
13	16 0	0	0	0	0	–	H
15	10 30	0	0	0	0	2	C
16	12 0	0	0	0	0	2	C
19	12 15	0	0	0	0	2	C
20	15 0	0	0	0	0	0	CK
21	13 30	0	0	0	0	1	C
22	14 15	0	0	0	0	0	C
23	12 15	0	0	0	0	0	C
26	13 30	0	0	0	0	0	C
Mar. 3	13 15	0	0	0	0	1	C
4	13 30	1	3	1	3	1	C
5	14 15	1	3	0	0	1	C
7	14 0	1	4	0	1	–	C
8	13 40	1	5	0	1	0	CK
9	12 20	1	3	0	0	0	CC
10	12 0	1	4	0	1	0	C
12	17 0	1	3	0	0	1	K

1890	E.S.C.T. h m	No. Gps.	No. of Spots	No. new Groups	No. new Spots	No. Gps Faculae	Sky
Mar. 16	10 10 15 30	0	0	0	0	1	C
17	12 30	0	0	0	0	1	C
18	13 40	0	0	0	0	1	C
19	17 30	0	0	0	0	–	K
20	10 30	0	0	0	0	0	C
24	13 30	0	0	0	0	1	C
26	17 0	0	0	0	0	1	KC
27	13 45	0	0	0	0	0	CK
30	16 15	0	0	0	0	0	KC
31	12 45 16 0	0	0	0	0	0	HK
Apr. 1	14 0	0	0	0	0	0	C
2	14 0	0	0	0	0	0	C
3	12 0	0	0	0	0	1	C
5	14 0	0	0	0	0	–	K
6	14 0	0	0	0	0	–	CK
8	7 30	0	0	0	0	–	C
10	11 10	0	0	0	0	3	C
11	14 15	2	7	2	7	0	C
12	11 15	2	6	0	2	–	C
13	14 0	2	7	0	0	0	C
14	11 0	0	0	0	0	3	C
15	12 30 14 0	1	4	1	4	1	C
16	11 45	1	1	0	0	1	C
17	10 45	0	0	0	0	3	C
18	10 30	0	0	0	0	2	C
19	15 05	0	0	0	0	3	C
20	16 45	0	0	0	0	0	C
21	15 40	0	0	0	0	0	C
22	11 0	0	0	0	0	0	C
24	16 0	1	1	1	1	1	C
25	11 0	0	0	0	0	1	C
26	11 0	0	0	0	0	–	KK
28	10 20	1	1	1	1	0	K
	17 15	1	2	0	1	0	C
29	14 35	1	9	0	8	0	C
30	14 10	2	7	0	0	1	C
May 2	12 45	0	0	0	0	5	C
3	12 20	0	0	0	0	1	C
5	18 10	0	0	0	0	–	KK
7	12 0	2	2	2	2	1	CK
8	15 45	1	2	0	1	1	K
9	12 15	1	9	0	7	2	C
11	10 15	2	12	1	3	3	C
12	9 30	1	8	0	0	3	CK
13	15 45	1	2	0	0	–	K
May 14	11 15	0	0	0	0	3	K
15	17 0	0	0	0	0	0	C
16	18 30	1	1	1	1	2	C
17	10 45	2	4	1	3	1	CK
18	12 30	2	6	0	2	3	C
21	10 30	2	3	0	0	2	C
22	12 0	1	1	0	0	5	H
23	13 45	1	3	0	2	1	C
24	11 30	1	1	0	0	3	C
25	10 0	1	2	1	1	2	C
27	15 0	1 ?	1 ?	0	0	3	CK
28	10 15	0	0	0	0	2	C
29	11 40	0	0	0	0	3	K
30	9 30 14 0	1	1	1	1	1	C
31	12 15	0	0	0	0	1	C
June 1	10 15	1	3	1	3	1	C
2	9 15	0	0	0	0	1	C
3	11 0	0	0	0	0	1	C
	16 30	1	1	1	1	1	C
5	11 0	1	5	1	5	2	C
7	11 15	1	5	0	0	2	K
8	10 0	1	3	0	0	4	C
9	13 10	2	5	1	2	2	C
10	11 0	1	2	0	0	1	CH
11	10 30 16 0	1	1	0	0	2	C
14	11 30	0	0	0	0	2	K
15	11 15	0	0	0	0	3	CK
16	10 15 14 0	0	0	0	0	3	C
17	10 40	0	0	0	0	3	C
18	10 15	0	0	0	0	1	C
19	14 15	0	0	0	0	0	C
20	11 30 16 0	0	0	0	0	0	C
21	11 0	0	0	0	0	2	C
22	10 0	0	0	0	0	1	C
23	17 0	0	0	0	0	2	K
24	11 30	0	0	0	0	0	C
25	16 30	0	0	0	0	1	C
26	9 0	0	0	0	0	2	CK
27	10 15	0	0	0	0	2	C
28	11 0 11 0	0	0	0	0	2	C
29	10 0	0	0	0	0	2	C
30	11 0	0	0	0	0	1	C
126 days		58	169	19	72	156	

C = Clear. K = Cloudy. H = Hazy.

These observations are in continuation of those published in no. 212 of this Journal.

The hours are expressed in Eastern Standard Civil Time (Greenwich minus 5h), reckoned from mean midnight.

The instrument and the methods of observation are the same as heretofore. The totals of new groups and new spots for the last six months of 1889 are 15 and 70, showing a slight increase of activity in 1890, although there has been a distinct lull since June 11, which has just now been ended by the appearance by rotation of a fine group of 8 spots on July 4-5.

The percentage of days without spots to the number of days of observations is 63; for the previous six months it was 57.

Conspicuous veiled spots have been observed as follows: Feb. 22, 1; 26, 3; April 14, 1; 19, 1; May 3, 3; 14, 1; 15, 1; June 2, 1; 3, 3; 19, a group. The observations on Jan. 7 and 14, and April 5, 6 and 8, were made by Student J. H. Procter.

II. Heliographic Latitude and Longitude of the Chief Spot of Each Observed Group.

Group No.	No. Sps. in Group	1890	E.S.C.T.	λ	l
			h m	°	°
0	1	Dec. 31, 1889	14 0	— 8.8	343.5
1	3	Jan. 9	7 0	—28.9	285.2
2	2	17	12 20	+22.9	153.3
2	5	18	12 45	+22.8	154.1
2*a*	4	21	12 30	+22.5	152.0
2*b*				+23.4	163.0
3	3	May 4	15 35	+32.5	194.9
3	3	5	14 0	+32.5	193.6
3	4	7	14 0	+32.6	191.2
3*a*	5	8	14 0	+33.0	194.3
3*b*				+32.4	195.3
3*a*	3	9	12 30	+33.3	192.0
3*b*				+31.8	192.8
3*a*	4	10	12 15	+33.7	191.7
3*b*				+31.7	192.7
4	2	Apr. 11	14 15	+25.7	136.9
5	5			—25.1	106.8
4	3	12	14 20	+25.7	137.1
5	3			—25.5	103.4
6 = 5	4	15	12 30	—26.9	101.6
7	1	24	17 25	+23.1	239.8
8 = 7	1	Apr. 28	12 30	+25.2	235.7
8*a*	7	30	12 00	+26.8	230.7
8*b*				+25.2	236.9
9	1	May 7	13 30	— 8.2	101.2
10	1			—28.2	48.1
10*a*	9	9	13 30	—26.4	55.8
10*b*				—28.4	51.4
11*a*	3	11	14 15	+23.7	135.7
11*b*				+20.9	138.7
12	1	17	14 0	+20.5	295.9
13	3			—34 2	8.2
12	1	18	12 40	+19.8	296.0
13	5			—33.7	8.4
14	2	25	10 0	+24	253
15	1	30	9 30	+24.5	248.8
16	1	June 1	10 20	+21.6	134.9
17	1	3	16 30	+ 7	196
18	5	5	14 35	—25.5	129.5
18	6	7	11 15	—24.6	132.1
19	2	10	14 20	—26.7	2.7

The mean latitude of the 11 northern groups is +22°.7; that of the 9 southern groups is —23°.6.

The activity has been nearly equal in the two hemispheres. This is in marked contrast to the condition in the last six months of 1889, and indicates a considerable transfer of activity to the northern hemisphere. Group No. 0 is No. 27 of 1889, and is properly included in the table, as it was observed on Jan. 2 and 3. It is not, however, included in the list of new groups. For the coordinates of Group No. 1, I am indebted to the great kindness of Mr. Maunder of the Royal Observatory, Greenwich. I have used the means of the position of the three umbrae measured on the Greenwich photograph.

The positions of the minute groups 14 and 17, I obtained from measurements on the projected diagram, instead of the usual Carrington's method. The positions are therefore less accurate than the others in the list.

The table shows several cases of intermittent activity. Group 5 was invisible on April 14 (sky clear), but appeared with 4 spots on April 15 as Group 6. Group 7 was first seen late in the afternoon of April 24, but was invisible on the following day (sky clear), though the group of faculae which had included the spot remained. It was not seen on the 26th (sky cloudy), but reappeared on the 28th as Group No. 8.

Group 4 died out on April 14; nearly a month later Group 11 broke out in the same place, and was absorbed in the surrounding faculae on the day following, May 13. On June 1, Group 16 developed in the same locality.

Group 14 was first seen on May 25, and was suspected on the 27th; it could not be seen on the 28th or 29th, but was replaced by Group 15 on May 30.

III. Spectroscopic Observations.

1890	No. of days of Observ'ns	No. of Prominences	No. of Prom. per Observat'n
January	5	9	1.8
February	10	31	3.1
March	5	27	5.4
April	16	58	3.6
May	11	35	3.2
June	8	29	3.6
	55	189	3.5
July–Dec. 1889	44	75	1.7

Prominences less than 20″ in height are not included.

I have added for comparison the totals for the previous six months in 1889. It thus appears that the revival of activity is more marked in the case of prominences than in that of spots.

Dartmouth College, Hanover, N.H., 1890 *July* 7.

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Ephemeris of Comet *a* 1890 (Brooks, March 19), by Mr. W. W. Campbell.
Solar Observations at Shattuck Observatory, January to July 1890, by Mr. Edwin B. Frost.

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POSITIONS OF COMPARISON-STARS DETERMINED AT ALBANY.

By LEWIS BOSS.

Early in 1887, the writer had formed the intention of computing accurate elements of the periodic comet of Finlay (1886 VII) from all observations which might become available. It was then decided, as the basis of the work, to determine with the meridian-circle the places of all comparison-stars for this comet, for which accurate positions at the present epoch could not readily be derived from then existing star-catalogues. The subjoined list contains the positions of stars observed at the Dudley Observatory in accordance with this program. It probably does not contain the places of all the comparison-stars in question which require redetermination, because, when the list was prepared, not all the observations of the comet had been published. A few numbers have crept into the list, the places of which might have been derived with all needful accuracy from existing material; but it was deemed best to err on the side of profusion of material rather than in the opposite direction. A few of the companion stars proved to be too faint to permit of accurate determination with the Olcott Meridian-Circle, and it was designed to obtain places for these through micrometer-comparisons with the equatorial. Star-positions, determined especially to facilitate this work, appear in the list below.

While the Finlay comet had a physical aspect which did not permit of extremely accurate determinations of position, there is some reason to suppose that lack of accuracy in individual observations, would, in a large degree, be compensated for by their multiplicity; and while it is quite probable that the systematic errors of observation to be apprehended might amount to sensible quantities, and also be variable in direction and magnitude at different periods of the comet's visibility, yet it seemed very desirable that such errors should be complicated as little as possible with further errors in the star-positions, either of an individual or systematic character. In the course of its apparition the comet passed from —27° to +25° of declination, and, therefore, across the region where there is likely to be least systematic homogeneity among the results of meridian observations.

The observations, the results of which are here presented, were strictly differential in character. The errors of the instrument both in right-ascension and declination were derived from the observation of stars, the positions of which are contained in the *American Ephemeris*. These were supplemented, however, by the addition of other standard star-positions reduced to systematic conformity with those of this *Ephemeris*.

The observations for the positions of all stars from 17^h to 23^h were made by Assistant H. V. Egbert alone. For nearly all the remaining stars, the transits were observed by the writer, and the circle was read by Egbert. For the comparison-stars, five wires were observed for transit, and two opposite microscopes were read for zenith-distance. Rarely were more than four standard stars observed in any one evening, and these were taken as nearly as possible on the parallel of the comparatively narrow zone of stars to be determined on any given occasion. The result has probably been close systematic accordance with the adopted standard star-positions, and, at the same time, a somewhat larger casual error of observation than might have been attained if more standard stars had been observed on each evening.

The probable error of observation has been derived from the comparison of pairs of observations. There were 177 such pairs available for the purpose. The mean discrepancy between two successive observations in right-ascension was $0^s.069$, and in declination, $0''.85$. These quantities give for the probable error of one observation, $\pm 0^s.041$ in right-ascension, and $\pm 0''.51$ in declination. Taking the observations in groups we have for the probable errors of a single determination:

57 pairs between —26 and —20, ±0.036 and ±0.58;
75 pairs between —20 and 0, ±0.040 and ±0.45;
45 pairs between + 5 and +24, ±0.050 and ±0.53.

The exclusion of a half dozen large discrepancies, principally occurring in the observation of faint stars, would very materially have reduced these probable errors. In each case where such discrepancies occur the star has been observed three or more times.

The magnitudes contained in the following list have been taken from the authorities cited in the second column, except in those cases where an asterisk is appended. The quantities so designated are the results of estimates made during observation by the writer.

It may be proper to mention here that M. Schulhof of the Bureau of Longitudes, Paris, has undertaken, for special reasons, the computation of definitive elements for the periodic comet of Finlay with the cordial concurrence of the writer, thus relieving the latter of any responsibility which he may have hitherto assumed in the matter.

Catalogue of Mean Places for 1887.0.

Number	Gould's Z. or DM. no.	Magn.	No. Obs.	Epoch	α 1887.0	Prec.	δ 1887.0	Prec.
					h m s	s	° ′ ″	″
1	C.Z. 872	7	1	87.63	17 13 29.67	+3.7234	−26 25 56.1	− 4.041
2	C.Z. 927	8.2	2	87.62	14 23.68	3.7207	−26 19 11.9	3.961
3	C.Z. 1005	8	1	87.63	15 22.29	3.7151	−26 6 5.6	3.880
4	C.Z. 1430	8.5	2	87.62	21 47.47	3.7336	−26 37 59.5	3.328
5	C.Z. 1813	8.5	2	87.62	27 43.60	3.7366	−26 39 38.6	2.816
6			1	87.65	38 37.56	3.7390	−26 36 3.1	1.868
7			2	87.65	54 43.56	3.7121	−26 37 19.4	0.462
8	C.Z. 3839	8	1	87.69	57 26.37	3.7193	−26 51 8.6	0.224
9	C.Z. 3977	8.5	2	87.62	59 13.20	3.7477	−26 47 50.1	− 0.068
10			3	87.66	18 4 14.48	3.7137	−26 39 58.8	+ 0.371
11	C.Z. 512	9.5	2	87.65	8 10.95	3.7369	−26 26 41.2	0.759
12			5	87.65	12 2.56	3.7159	−26 46 52.4	1.053
13			2	87.67	12 2.91	3.7462	−26 46 45.3	1.054
14	C.Z. 1071	9	2	87.62	17 37.52	3.7385	−26 33 2.4	1.541
15	C.Z. 1501	8.5	3	87.66	25 11.54	3.7371	−26 34 18.1	2.200
16	C.Z. 1543	9	2	87.69	26 3.98	3.7280	−26 16 4.5	2.276
17			2	87.66	34 47.65	3.7285	−26 24 0.5	3.033
18			1	87.65	35 1.14	3.7263	−26 18 43.4	3.053
19	C.Z. 2066	9	2	87.69	36 42.01	3.7256	−26 19 44.6	3.198
20			1	87.68	40 4.91	3.7212	−26 20 12.4	3.489
21			3	87.66	40 10.13	3.7210	−26 19 58.9	3.497
22	C.Z. 2438	9.5	3	87.66	44 11.87	3.7166	−26 8 54.7	3.843
23			2	87.69	48 48.82	3.7120	−26 4 38.2	4.239
24	C.Z. 2860	9.5	3	87.66	53 51.44	3.7028	−25 52 1.7	4.669
25	C.Z. 2870	9.5	3	87.66	54 1.22	3.7031	−25 52 44.9	4.684
26	C.Z. 451	9	2	87.70	19 11 7.52	3.6735	−25 16 21.3	6.124
27	C.Z. 460	9.5	2	87.70	11 22.77	3.6732	−25 16 16.1	6.145
28	C.Z. 1801	9	2	87.70	43 37.02	3.6052	−23 53 33.3	8.761
29			2	87.71	48 10.36	3.6012	−23 56 10.4	9.117
30	C.Z. 2102	9.2	2	87.71	51 52.52	3.5976	−23 58 40.3	9.405
31	C.Z. 2303	8.7	3	87.73	57 18.80	3.5803	−23 32 29.3	9.823
32			1	87.71	20 2 6.59	3.5617	−23 1 0.4	10.186
33			2	87.71	2 7.74	3.5618	−23 1 14.9	10.188
34	C.Z. 72	9	3	87.74	2 37.73	3.5654	−23 12 3.1	10.225
35			2	87.71	5 27.26	3.5558	−22 56 49.6	10.437
36			2	87.73	6 35.28	3.5564	−23 2 9.1	10.521
37	C.Z. 231	9	2	87.78	7 32.87	3.5594	−23 13 10.8	10.593
38			2	87.71	8 29.08	3.5516	−22 56 5.3	10.662
39	DM. −22°5385	7.8	2	87.73	11 27.05	3.5341	−22 20 48.8	10.881
40	DM. −22 5389	8.5	2	87.71	12 33.20	3.5357	−22 28 45.0	10.962
41	DM. −22 5402	9.3	2	87.73	15 5.12	3.5296	−22 21 38.6	11.147
42	DM. −22 5419	8.1	2	87.71	17 43.56	3.5272	−22 24 46.0	11.338
43	DM. −21 5717	8.7	2	87.78	18 53.66	3.5140	−21 51 6.7	11.423
44	DM. −22 5425	8.6	2	87.73	18 56.53	3.5170	−22 1 38.2	11.426
45	DM. −22 5435	8.0	2	87.73	21 28.00	3.5217	−22 23 38.1	11.607
46	DM. −21 5737	9.0	2	87.71	23 28.11	3.5021	−21 37 57.5	11.749
47	DM. −21 5767	8.8	2	87.71	29 47.38	3.4878	−21 22 6.1	12.193
48	DM. −21 5775	9.7	2	87.73	30 44.54	3.4892	−21 29 53.2	12.259
49	DM. −21 5784	9.0	2	87.78	32 24.46	3.4867	−21 29 24.1	12.374
50	DM. −21 5791	9.1	2	87.71	33 52.89	3.4873	−21 37 1.4	12.475
51	DM. −21 5797	9.0	2	87.73	34 59.80	3.4771	−21 12 44.1	12.551
52	DM. −21 5805	8.8	2	87.71	20 36 39.35	+3.4748	−21 12 52.4	+12.664

Number	DM. Number	Magn.	No. Obs.	Epoch	α 1887.0	Prec.	δ 1887.0	Prec.
53	DM. —21°5812	8.3	2	87.80	20 37 39.30	+3.4814	—21 35 54.1	+12.732
54	DM. —20 6019	9.3	2	87.78	37 50.78	3.4612	—20 47 2.5	12.715
55	DM. —20 6023	9.0	2	87.73	38 46.98	3.4634	—20 48 37.2	12.808
56	DM. —21 5821	9.0	2	87.80	39 49.72	3.4619	—20 57 8.7	12.878
57	DM. —20 6025	9.1	2	87.78	39 52.68	3.4602	—20 43 37.0	12.882
58	DM. —21 5839	8.5	2	87.73	42 24.83	3.4628	—21 2 6.8	13.051
59	DM. —21 5840	8.0	3	87.71	42 43.10	3.4625	—21 2 31.1	13.071
60	DM. —20 6053	8.8	2	87.71	45 30.34	3.4429	—20 16 0.5	13.255
61	DM. —20 6055	7.0	2	87.80	45 48.36	3.4385	—20 3 57.9	13.275
62	DM. —20 6068	9.8	3	87.77	48 35.79	3.4408	—20 23 1.6	13.457
63			1	87.79	48 41.26	3.4407	—20 23 9.0	13.465
64	DM. —20 6073	9.1	2	87.71	49 51.06	3.4316	—20 0 33.8	13.538
65	DM. —19 5984	9.0	2	87.78	53 10.80	3.4165	—19 28 21.3	13.752
66	DM. —20 6096	8.3	1	87.71	54 27.51	3.4316	—20 21 27.5	13.835
67	DM. —19 5991	8.3	2	87.73	55 1.72	3.4117	—19 21 32.7	13.869
68	DM. —19 5999	8.5	2	87.71	56 41.56	3.4170	—19 45 43.3	13.974
69	DM. —19 6022	8.2	2	87.73	21 0 43.34	3.3998	—19 9 15.0	14.224
70	DM. —19 6026	9.0	3	87.81	1 37.99	3.4026	—19 22 15.4	14.280
71	DM. —17 6187	10	1	87.79	1 46.15	3.3656	—17 21 17.1	14.290
72	DM. —19 6028	8.3	2	87.80	2 26.87	3.3978	—19 10 58.9	14.330
73	DM. —19 6038	8.7	3	87.82	3 59.98	3.3907	—18 55 0.7	14.425
74	DM. —18 5875	8.0	2	87.78	4 10.42	3.3882	—18 47 22.2	14.436
75	DM. —18 5891	8.3	2	87.71	8 10.64	3.3750	—18 22 19.4	14.677
76	DM. —18 5910	9.5	2	87.71	13 26.39	3.3630	—18 6 40.5	14.987
77	DM. —18 5919	9.4	2	87.71	16 46.47	3.3581	—18 3 38.1	15.150
78	DM. —17 6272	8.5	2	87.75	20 27.70	3.3470	—17 45 25.1	15.388
79	DM. —17 6297	9.0	2	87.71	23 51.33	3.3332	—17 12 14.3	15.576
80	DM. —16 5885	7.2	2	87.71	27 25.62	3.3202	—16 41 51.7	15.771
81	DM. —17 6312	9.0	1	87.79	28 12.25	3.3277	—17 14 50.4	15.843
82			1	87.79	28 15.17	3.3276	—17 14 49.2	15.846
83	DM. —17 6313	9.1	3	87.79	28 25.40	3.3273	—17 14 29.1	15.825
84	DM. —17 6314	8.5	3	87.83	28 25.59	3.3239	—17 1 30.0	15.825
85	DM. —17 6315	8.9	2	87.75	28 33.04	3.3270	—17 14 0.4	15.832
86	DM. —16 5889	8.7	2	87.82	28 58.81	3.3191	—16 46 2.8	15.855
87	DM. —17 6318	8.5	2	87.71	29 30.31	3.3245	—17 9 30.6	15.983
88	DM. —16 5924	8.0	2	87.78	36 20.92	3.3014	—16 16 32.1	16.241
89	DM. —15 6058	8.5	3	87.83	39 37.16	3.2878	—15 39 6.9	16.408
90	DM. —15 6060	9.0	2	87.75	39 58.50	3.2889	—15 45 16.2	16.425
91	DM. —15 6065	7.7	2	87.80	41 0.47	3.2771	—15 2 5.2	16.477
92	DM. —15 6064	8.5	2	87.83	41 1.16	3.2796	—15 12 18.2	16.478
93	DM. —15 6075	7.5	2	87.75	43 2.34	3.2831	—15 38 43.7	16.578
94	DM. —15 6090	8.8	2	87.84	48 33.92	3.2684	—15 7 6.2	16.845
95	DM. —14 6163	7.8	2	87.80	49 59.92	3.2592	—14 31 14.0	16.913
96	DM. —14 6181	8.8	5	87.82	53 31.76	3.2168	—13 58 11.7	17.077
97	DM. —14 6187	7.5	2	87.81	54 30.71	3.2551	—14 42 20.2	17.122
98	DM. —13 6136	9.0	3	87.83	22 7 44.89	3.2207	—13 15 32.9	17.696
99	DM. —12 6230	9.1	3–1	87.84	11 30.54	3.2074	—12 28 52.7	17.848
100	DM. —12 6235	9.3	2	87.83	12 33.78	3.2081	—12 39 26.4	17.890
101	DM. —12 6236	8.0	2	87.84	12 54.22	3.2018	—12 7 21.9	17.903
102	DM. —11 5821	8.3	2	87.83	17 56.37	3.1892	—11 27 22.1	18.198
103	DM. —11 5864	8.3	2	87.84	27 42.85	3.1753	—11 6 8.9	18.449
104	DM. —11 5865	9.5	2	87.83	27 47.87	3.1736	—10 56 16.9	18.452
105	DM. —10 5959	9.9	2	89.80	32 3.41	3.1645	—10 25 10.4	18.595
106	DM. —10 5965	9.1	2	87.83	33 31.37	3.1609	—10 10 27.0	18.643
107	DM. — 9 6037	8.5	3	87.83	37 4.02	3.1558	— 9 44 11.0	18.755
108	DM. — 9 6043	9.0	3	87.85	38 18.03	3.1515	— 9 36 52.6	18.792
109	DM. — 9 6044	9.2	3	87.87	38 19.84	3.1518	— 9 39 21.1	18.793
110	DM. — 9 6045	9.4	3	87.86	38 33.55	3.1470	— 9 5 56.8	18.800
111	DM. — 9 6053	10	3	87.84	40 25.57	3.1444	— 8 59 1.6	18.857
112	DM. — 9 6060	9.5	1	87.85	42 12.66	3.1452	— 9 16 37.6	18.909
113	DM. — 9 6061	9.5	2	87.87	42 24.83	3.1442	— 9 10 54.1	18.915
114	DM. — 8 5952	8.0	2	87.84	22 42 28.12	+3.1404	— 8 12 30.7	+18.917

Number	DM. Number	Magn.	No. Obs.	Epoch	α 1887.0	Prec.	δ 1887.0	Prec.
					h m s	s	° ′ ″	″
115	DM. — 9°6063	9.1	2	87.83	22 43 0.12	+3.1465	— 9 32 19.9	+18.932
116	DM. — 8 5980	8.7	2	87.83	49 52.30	3.1321	— 8 25 21.6	19.122
117	DM. — 8 5996	8.7	3	87.83	53 48.40	3.1260	— 7 59 59.8	19.222
118	DM. — 7 5907	9.4	4	87.86	54 45.90	3.1240	— 7 48 33.8	19.216
119	DM. — 7 5910	6.8	2	87.81	55 31.31	3.1224	— 7 40 3.4	19.265
120	DM. — 7 5925	8.0	1	87.82	58 31.14	3.1178	— 7 47 52.2	19.336
121	DM. — 6 6140	8.8	2	87.84	58 36.26	3.1146	— 6 47 15.4	19.338
122	DM. — 6 6165	9.5	1	87.90	23 7 5.89	3.1051	— 6 5 6.1	19.521
123	DM. — 6 6167	9.1	2	87.84	7 33.32	3.1068	— 6 27 56.6	19.530
124	DM. — 6 6175	9.5*	4	87.89	9 33.27	3.1039	— 6 9 11.0	19.569
125	DM. — 4 5868	6.5	2	87.95	14 24.34	3 0931	— 4 32 2.7	19.658
126	DM. — 5 5977	9.2	2	87.83	16 55.36	3.0942	— 4 58 2.0	19.700
127	DM. — 4 5880	9.7	1	87.88	17 36.31	3.0926	— 4 44 59.7	19.711
128	DM. — 5 5986	9.2	3	87.87	19 24.58	3.0938	— 5 11 11.0	19.739
129			3	88.50	23 21.18	3.0828	— 2 47 22.5	19.797
130	DM. — 4 5890	8.5	4–3	88.88	23 33.29	3.0881	— 4 13 3.8	19.800
131	DM. — 4 5891	8.8*	2	87.94	24 23.45	3.0867	— 3 56 43.0	19.811
132	DM. — 4 5897	8.8	3	88.51	25 43.00	3.0864	— 3 59 17.1	19.829
133	DM. — 3 5651	9.4	2	87.83	26 53.55	3.0850	— 3 44 2.6	19.844
134	DM. — 3 5661	7.7	2	87.91	27 53.23	3.0818	— 2 52 4.1	19.857
135	DM. — 4 5907	9.5*	2	87.93	28 14.36	3.0850	— 3 53 13.6	19.861
136	DM. — 4 5913	8.9	2	87.87	29 37.57	3.0850	— 4 3 51.5	19.877
137	DM. — 3 5669	8.0	2	87.83	30 56.52	3.0826	— 3 35 12.6	19.892
138		9.0*	1	87.93	33 29.31	3.0800	— 2 48 8.5	19.919
139	DM. — 2 6007	8.6*	2	87.93	33 35.43	3.0799	— 2 16 50.0	19.920
140	DM. — 2 6021	8.3	3	87.84	36 33.72	3.0775	— 2 7 37.0	19.948
141	DM. — 2 6040	9.5	3–4	88.34	42 13.39	3.0759	— 1 54 18.0	19.993
142	DM. — 1 4506	9.0	2	87.83	51 2.40	3.0733	— 1 8 22.4	20.038
143	DM. + 4 95	8.8*	1	87.95	0 36 25.07	3.0912	+ 5 4 23.4	19.801
144	DM. + 4 102	9.1*	2	87.95	37 30.41	3.0920	+ 5 7 19.0	19.785
145	DM. + 5 102	7.7*	2	87.91	40 15.78	3.0949	+ 5 28 14.2	19.745
146	DM. + 5 109	7.6*	2	87.94	43 49.52	3.0982	+ 5 47 26.4	19.688
147	DM. + 5 113	9.8*	2	87.94	45 2.40	3.0976	+ 5 29 25.6	19.667
148	DM. + 6 125	10.0*	2	87.94	50 48.32	3.1053	+ 6 22 23.7	19.562
149	DM. + 6 147	7.9*	2	87.94	56 57.09	3.1122	+ 6 53 33.3	19.437
150	DM. + 7 156	9.2*	2	87.94	58 1.55	3.1155	+ 7 19 48.8	19.414
151	DM. + 7 162	8.6*	2	87.94	59 19.12	3.1162	+ 7 16 5.4	19.389
152	DM. + 7 177	9.0*	2	87.94	1 3 29.91	3.1239	+ 8 0 37.6	19.288
153	DM. + 8 184	9.2*	2	87.94	5 48.69	3.1290	+ 8 29 22.8	19.252
154	DM. + 7 183	9.0*	2	87.96	6 14.10	3.1240	+ 7 42 30.1	19.221
155	DM. + 7 184	8.8*	2	87.94	6 26.94	3.1257	+ 7 56 2.5	19.216
156	DM. + 8 187	8.2	2	87.94	7 47.51	3.1298	+ 8 22 31 5	19.182
157	DM. + 8 200	8.4*	2	87.94	10 34.25	3.1369	+ 9 1 45.7	19.110
158	DM. + 8 209	8.3*	4	88.87	14 27.70	3.1395	+ 8 55 52.4	19.004
159	DM. + 8 216	8.1*	2	87.96	15 48.22	3.1421	+ 9 6 47.8	18.966
160	DM. + 9 172	8.0*	2	87.96	23 8.09	3.1548	+ 9 50 48.4	18.748
161	DM. +10 200	9.5*	3	88.56	26 25.58	3.1658	+10 44 27.5	18.644
162	DM. +10 202	8.8*	2	87.96	27 26.64	3.1639	+10 24 10.0	18.611
163	DM. +10 210	9.7*	2	87.96	30 38.04	3.1706	+10 47 10.9	18.505
164	DM. +10 221	8.5*	2	87.96	34 55.42	3.1743	+10 13 3.0	18.358
165	DM. +12 223	8.4*	3	88.56	38 20.45	3.1934	+12 15 49.8	18.235
166	DM. +11 228	8.8*	2	87.96	38 40.78	3.1902	+11 55 3.5	18.223
167	DM. +11 231	8.6*	2	87.96	40 37.10	3.1917	+11 50 52.1	18.151
168		9.2*	3	88.58	42 41.93	3.1995	+12 22 12.7	18.073
169	DM. +11 237	9.0*	3–4	88.88	43 15.62	3.1966	+12 1 54.5	18.052
170	DM. +12 242	9.9*	2	87.96	44 56.73	3.2018	+12 20 53.5	17.987
171	DM. +12 245	9.4*	3	88.59	45 47.60	3.2068	+12 42 43.3	17.954
172	DM. +13 296	7.8*	2	87.96	48 43.00	3.2157	+13 12 3.8	17.839
173	DM. +12 254	8.3*	2	87.96	50 14.58	3.2165	+13 3 11.3	17.757
174	DM. +13 351	7.4*	2	87.96	2 6 35.48	3.2394	+13 23 14.2	17.071
175	DM. +17 432	9.0*	3	88.59	39 32.57	3.3423	+17 28 8.4	15.387
176	DM. +18 370	8.6*	2	87.96	2 47 25.36	+3.3653	+18 10 16.3	+14.936

Number	DM. Number	Magn.	No. Obs.	Epoch	α 1887.0	Prec.	δ 1887.0	Prec.
					h m s	s	° ′ ″	″
177	DM. +18° 377	9.0*	2	88.00	2 49 42.67	+3.3730	+18 25 39.8	+14.802
178		10.0*	2	88.02	50 19.44	3.3719	+18 29 21.1	14.766
179		9.8*	2–3	88.60	50 31.40	3.3763	+18 32 56.7	14.754
180	DM. +18 378	9.0*	1	87.96	50 43.70	3.3782	+18 38 34.1	14.742
181	DM. +18 382	8.2*	2	87.99	52 0.13	3.3821	+18 46 37.1	14.666
182	DM. +18 391	8.2*	3	87.98	51 46.73	3.3897	+18 57 17.3	14.199
183	DM. +19 471	7.5*	2	88.02	3 3 18.82	3.4133	+19 34 12.5	13.973
184	DM. +19 479	8.7*	2	87.98	5 27.53	3.4205	+19 46 57.2	13.838
185	DM. +20 541	8.5*	2	87.99	14 29.00	3.4423	+20 14 18.2	13.256
186	DM. +20 581	9.0*	2	87.99	25 18.94	3.4736	+21 1 22.2	12.530
187	DM. +20 584	8.9*	1	87.97	25 32.53	3.4742	+21 2 18.2	12.515
188	DM. +21 490	8.8*	2	87.99	31 20.82	3.4884	+21 20 14.3	12.114
189	DM. +21 492	8.0*	2	87.99	32 37.29	3.4934	+21 28 28.6	12.025
190	DM. +21 676	9.3*	1	88.01	4 33 41.54	+3.6317	+24 13 10.7	+ 7.375

ELEMENTS AND EPHEMERIS OF COMET *b* 1890.

BY LEWIS BOSS.

The comet discovered by COGGIA on July 18 has been observed by me at Albany, on July 22 and 27. Elements of this comet are herewith presented, which are derived from these two Albany observations, combined with an observation made at Marseilles on July 19.

$$T = 1890,\ \text{July } 8.6486,\ \text{G.M.T.}$$
$$\left.\begin{aligned}\omega &= 85^\circ\ 53'\ 26''\\ \Omega &= 14\ \ 24\ \ 50\\ i &= 63\ \ 15\ \ \ 2\end{aligned}\right\}\ 1890.0$$
$$\log q = 9.88403$$

The outstanding discrepancies (C—O) for the observation of July 22 are: $\Delta\lambda \cos\beta = -4''$; $\Delta\beta = -16''$. These differences cannot be made materially smaller, on the assumption that the orbit is a parabola. The zenith distance of the comet at the Marseilles observation was more than 86°, and in the Albany observation of July 27 more than 81°. Therefore these residuals are, perhaps, no larger than might reasonably have been expected as due to error of the observation.

The brightness at the Marseilles observation of July 19 is taken as unity in the following:

EPHEMERIS FOR GREENWICH MIDNIGHT.

Gr. M.T.	α	δ	log *r*	log Δ	Light
	h m s	° ′			
1890 Aug. 1	10 17 16	+33 6.0	9.9515	0.2307	0.67
3	10 27 0	31 20.3	9.9611	0.2375	
5	10 35 36	29 35.6	9.9710	0.2446	0.57
7	10 43 37	27 52.3	9.9810	0.2518	
9	10 51 8	26 10.6	9.9912	0.2591	0.49
11	10 58 11	24 31.0	0.0014	0.2665	
13	11 4 49	22 53.5	0.0116	0.2740	0.41
15	11 11 5	21 18.4	0.0218	0.2815	
17	11 17 1	19 45.7	0.0320	0.2889	0.35
19	11 22 38	18 15.5	0.0422	0.2964	
21	11 27 59	16 47.8	0.0522	0.3037	0.30
23	11 33 6	15 22.6	0.0622	0.3111	
25	11 38 0	13 59.8	0.0720	0.3183	0.26

The heliocentric coordinates referred to the equator of 1890.0 are:

$$x = r\,[9.98900]\sin(v + 182^\circ\ 29'\ 21'')$$
$$y = r\,[9.36671]\sin(v + 164\ \ 51\ \ 54\ )$$
$$z = r\,[9.99897]\sin(v + \ 91\ \ 35\ \ 24\ )$$

NOTE ON THE VARIABLE STAR S *MONOCEROTIS*.

BY PAUL S. YENDELL.

This star, which seems to have been much neglected, is of rather particular interest, as having the shortest period of any known variable which is certainly not of the *Algol*-type.

There appears to have been no attempt to improve upon the elements assigned by WINNECKE (*A.N.*, Vol. 76, p. 249), which SCHÖNFELD, in the notes to his Second Catalogue says, "my observations partly confirm, partly contradict."

This expression exactly defines my own experience with this star during the past two winters, during which I have paid it considerable attention. The weather has been most unfavorable, as there have been few occasions on which the sky was clear enough for observation during a whole period of the star; these occasions, however, when they have occurred, have been carefully improved during the past season, and the result is in a high degree unsatisfactory; the light-changes are small, and the star's position in the middle of a brightish cluster, which is more or less conspicuous, according to the state of the atmosphere, renders observation difficult, and at times has raised a doubt of the reality of the star's variation.

The changes noted have been to a considerable extent irregular, the extreme variation observed being only five steps, or about 0ᴹ.7, and at times, for several days in succession, the star would apparently remain constant, or vary only one or two steps. In the two seasons' work, my observations indicate seven maxima and seven minima, as follows. The comparisons are with WINNECKE's elements.

Maxima	w	O—C	Minima	w	O—C
1889 Nov. 16.2	3	+1.60	1889 Nov. 22.8	2	—1.1
Dec. 6.5	1	+1.24*	29.5	3	—1.3
13.4	1	+1.25	1890 Jan. 14.2	3	—0.37
21.3	3	—1.10	22.4	2	+1.0
1890 Jan. 16.2	3	+0.60	Feb. 21.4	3	±0.0
1890 Apr. 6.5	3	+1.73	1890 Apr. 11.6	3	+1.0
12.8	3	+1.15	15.3	3	+1.3

* Moonlight.

The above residuals are intolerably large; but by reason of the fewness and scattered character of the observed epochs, it has been impracticable to fix certainly the nature of the corrections implied; several attempts to form mean light-curves on different periods have been attended with uniformly unsatisfactory results.

The impression left by a careful consideration of all my observations, after many attempts to reconcile them with some sort of period, is, that if variable the star's changes are rather of the nature of those of *V Sagittarii* or *R Coronae*, that is, of an irregular character, with times of sudden fluctuation, alternating without regularity with periods of nearly stationary light.

It is much to be desired that a continuous line of observations of this star could be obtained, extending over several months, and made at least twice each night, at intervals of not less than six hours. I have, myself, tried the experiment with a shorter interval, and the impression remaining is, that in these cases the results are, in all probability, mainly illusory.

Dorchester, Mass., 1890 *July* 23.

OBSERVATIONS OF COMET *b* 1890 (*COGGIA*).

MADE ON THE 12-INCH EQUATORIAL OF THE LICK OBSERVATORY.

BY W. W. CAMPBELL.

1890 Greenwich M.T.	*	No. Comp.	☄ — *		☄'s apparent		log $p\Delta$	
			$\Delta\alpha$	$\Delta\delta$	α	δ	for α	for δ
d h m s			m s	′ ″	h m s	° ′ ″		
July 22 17 1 56	1	8 , 8	+0 55.49	+1 11.9	9 20 44.81	+41 31 24.1	9.756	0.771
23 17 15 12	2	10 , 6	—3 49.24	—1 51.1	9 27 39.66	+40 12 13.1	9.742	0.788

Mean Places for 1890 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	9 19 50.01	—0.69	+41 30 7.1	+5.1	W.B., IX 363
2	9 31 29.56	—0.66	+40 43 58.8	+5.4	Poulkova 1518

Mt. Hamilton, 1890 *July* 24.

FILAR-MICROMETER OBSERVATIONS OF COMET *b* 1890.

MADE AT THE DUDLEY OBSERVATORY.

BY LEWIS BOSS.

1890 Albany M.T.	*	No. Comp.	☄ — *		☄'s apparent		log $p\Delta$	
			$\Delta\alpha$	$\Delta\delta$	α	δ	for α	for δ
d h m s			m s	′ ″	h m s	° ′ ″		
July 22 9 15 41	1	15 , 5	—0 47.68	—3 32.1	9 19 54.55	+41 37 6.7	9.703	0.820
27 9 23 32	2	5 , 2	—4 38.93	+1 53.6	9 51 52.94	+37 24 57.2	9.681	0.822

Mean Places for 1890.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	9 20 42.92	—0.69	+41 40 33.6	+5.2	Lal. 18562 and W.B., IX 389
2	9 56 32.41	—0.54	+37 22 58.3	+5.3	Lund A.G. Zones 150 and 167

The observations are corrected for differential refraction. In the observation of July 27, the comet was extremely faint and difficult to observe, owing to the presence of a slight fog strongly illuminated by moonlight

OBSERVATIONS OF COMET *a* 1890 (BROOKS),

MADE AT THE U.S. NAVAL OBSERVATORY WITH THE 9.6-INCH EQUATORIAL

By Prof. E. FRISBY.

[Communicated by Captain F. V. McNair, Superintendent.]

1890 Washington M.T.	✱	No. Comp.	☌ — ✱ Δα	☌ — ✱ Δδ	☌'s apparent α	☌'s apparent δ	log pΔ for α	log pΔ for δ
d h m s			m s	′ ″	h m s	° ′ ″		
June 13 11 3 24.5	1	15 , 3	—2 2.00	+2 41.1	17 24 3.86	+65 22 14.6	n9.515	n0.565
18 10 7 51.1	2	10 , 2	—0 54.39	+0 44.2	16 28 59.44	+65 44 22.5	n9.161	n0.597
30 9 21 42.2	3	20 , 4	—1 24.62	—8 30.1	14 43 41.36	+61 52 57.8	9.493	n0.497
July 8 11 46 4.6	4	20 , 4	+1 7.41	+3 45.6	14 1 45.24	+57 35 5.6	9.914	0.105
10 10 49 38.6	5	20 , 4	—1 27.96	+8 47.3	13 54 18.62	+56 30 8.9	9.870	9.628
18 9 37 7.1	6	20 , 4	—2 33.88	+3 33.6	13 31 45.43	+52 13 14.4	9.817	9.126

Mean Places for 1890.0 of Comparison-Stars.

✱	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	17 26 2.57	+3.29	+65 19 34.1	— 0.6	Oe. Arg. N. 17204
2	16 29 50.66	+3.17	+65 43 33.3	+ 5.0	Oe. Arg. N. 16331
3	14 45 4.12	+1.86	+62 1 15.1	+12.8	Bonn VI, 62° 1368
4	14 0 36.72	+1.11	+57 31 6.0	+14.0	Krueger's Zones 138, 33 ; 112.1
5	13 55 45.59	+0.99	+56 21 7.5	+14.1	Rümker 4559
6	13 34 18.71	+0.60	+52 9 27.4	+13.4	Bonn VI, 52° 1721

OBSERVATIONS OF COMET *a* 1890,

MADE AT THE VASSAR COLLEGE OBSERVATORY WITH THE 12-INCH EQUATORIAL

BY MARY W. WHITNEY.

1890 Greenwich M.T.	✱	No. Comp.	☌ — ✱ Δα	☌ — ✱ Δδ	☌'s apparent α	☌'s apparent δ	log pΔ for α	log pΔ for δ
d h m s			m s	′ ″	h m s	° ′ ″		
May 2 20 15 15.5	1	13 . 11	—0 2.13	+4 23.0	20 58 6.7	+31 6.9	n9.548	0.112
15 20 22 4.8	2	3	+5 31.70	+1 28.5	20 34 34.95	42 50 13.1	n9.371	9.241
17 20 33 26.6	3	7	—0 51.46	—2 47.4	20 29 6.30	41 44 50.6	n9.518	9.324
20 19 16 16.5	4	5	—3 9.42	+4 27.5	20 19 27.84	47 37 47.9	n9.521	n9.400
22 19 29 43.2	5	10	+0 12.10	+3 33.7	20 11 44.1	49 39.5	n9.441	n9.898
24 16 21 59.2	6	2	+1 35.81	—2 55.8	20 3 44.96	51 28 14.3	n9.841	0.210
27 17 7 55.6	7	7	+1 21.41	—3 11.9	19 48 55.89	54 18 50.5	n9.753	0.218
28 15 56 50.4	8	7	+3 41.70	+1 56.2	19 43 21.75	55 13 56.9	n9.842	0.722
June 2 15 17 8.9	9	8	—3 18.90	—0 21.4	19 10 22.43	+59 29 47.4	n9.870	9.236

Mean Places for 1890.0 of Comparison-Stars.

✱	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	20 58 8.9	—0.09	+31 2.8	—16.2	DM. 30° 1293
2	20 29 2.63	+0.62	+42 49 1.2	—16.6	Radcliffe 4851
3	20 29 57.06	+0.70	+41 47 54.5	—16.5	½[Radcliffe 4859 + Gr. (1887) 1450]
4	20 22 36.38	+0.88	+47 33 36.6	—16.2	Argelander, Zone 134, no. 90
5	20 11 30.9	+1.10	+49 36.2	—15.6	DM. 49° 3233
6	20 2 7.86	+1.29	+51 31 25.3	—15.2	Greenwich (1880) no. 3328
7	19 47 32.91	+1.57	+54 22 16.7	—14.3	Struve 2376
8	19 39 38.39	+1.66	+55 12 11.7	—11.0	Bonn, VI 55° 2215
9	19 13 39.10	+2.23	+59 30 20.0	—11.2	Bonn, VI 59° 1982

COMET *b* 1890.

A bright comet was discovered by COGGIA July 18, and observed at Marseilles, as follows:

July 19.3861 Greenw. M.T. $\alpha = 8^h\ 55^m\ 58^s$, $\delta = +44°\ 22'\ 48''$.

Daily motion, 1° 51′ in α, and 0° 42′ southward.

Mr. RITCHIE has kindly transmitted the following additional observations from Harvard College Observatory, which have been sent him by telephone for the *Science Observer*.

July 21.6316. $\alpha = 9^h\ 13^m\ 3^s.2$, $\delta = +42°\ 22'\ 10''$.
22.5892. 9 19 51 .1, 41 37 12 .
23.5839. 9 26 45 .6, +40 48 52 .

ELEMENTS AND EPHEMERIS OF COMET *b* 1890 (*COGGIA*).

BY WILLIAM BELLAMY.

Computed from the position observed at Marseilles July 19, and two observed by WENDELL at Harvard College Observatory July 21 and 22.

$T =$ 1890 July 9.6223 Gr. M.T.

$$\left.\begin{array}{l}\omega = 87°\ 40'.5\\ \Omega = 15\ \ 22\ .4\\ i = 62\ \ 46\ .7\end{array}\right\}\ 1890.0$$

$\log q = 9.8892$

Middle place, C—O. $\lambda = 0'.0$, $\beta = +0'.2$

EPHEMERIS FOR GREENWICH TIME.

Gr. M.T.	α h m	δ ° ′	log r	log Δ	Br.
1890 July 26.5	9 45.5	+38 22	9.9249	0.2118	0.82
30.5	10 8.0	34 52			
Aug. 3.5	27.4	31 18	9.9595	0.2363	0.36
7.5	44.2	27 48			
11.5	10 58.9	24 24	9.9986	0.2615	0.46
13.5	11 5.6	22 46			
15.5	12.0	21 10			
17.5	18.0	19 35			
19.5	11 23.7	18 2	0.0388	0.2938	0.33

COMET *c* 1890.

A faint comet was discovered by DENNING July 23.5 Greenwich M.T., in right-ascension $15^h\ 12^m$, and decl. +78°. Motion rapid eastward.

Mr. RITCHIE kindly transmits the following additional observation received by telegraph from Lick Observatory.

July 25.9893. $\alpha = 15^h\ 14^m\ 18^s$, $\delta = +76°\ 2'\ 14''$.

NEW ASTRONOMICAL WORK.

Publication IV. der königlichen Sternwarte zu Kiel.

This appendix to the two volumes of Zones, between 55° and 65° N. Decl., observed by Prof. KRUEGER at Helsingfors and Gotha, contains a series of revision-observations for the zone-catalogue, and sundry corrections to the original zones.

Prof. KRUEGER invites astronomers, who already possess the two published volumes, and desire this supplement, to inform him of their wish, with which it will give him pleasure to comply.

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NEW ASTRONOMICAL WORK.

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THE LATITUDE OF THE NAVAL OBSERVATORY.

By A. HALL.

In the *Publications of the Astronomical Society of the Pacific*, Vol. II. p. 136, Professor E. S. HOLDEN has called attention to the latitude of the Naval Observatory determined from observations with the Mural Circle. The early volumes of the Observatory show that a great deal of care and attention were given to this instrument, but a more complete investigation of its errors, and of the values of the latitude found by means of it, would certainly be interesting, and would be well worth undertaking while the circle remains in its present position.

At a meeting of the Geodetic Conference held at Rome in 1883, Mr. FERGOLA presented evidence which seemed to show that latitudes in the northern hemisphere are undergoing a secular diminution, and he proposed that observatories in nearly the same latitude, and differing much in longitude, should determine their differences of latitude by means of observations in the Prime Vertical, in order that a future determination from the same stars and with similar instruments might settle the question of secular change. An effort was made to carry out this proposal, but apparently not much has been done. At that time I collected some data on the latitude of this Observatory, and the determinations seemed to confirm the results arrived at by Mr. FERGOLA. The values of the latitude found by observations with the meridian instruments are as follows:

$$1846,\quad \varphi = +38^\circ\ 53'\ 39''.23$$
$$1863,\quad 38.78$$
$$1875,\quad 38.38$$

which shows a diminution of 0″.85.

The first value is the result of a discussion by Mr. SEARS C. WALKER of the observations of circumpolar stars with the Mural Circle by Professor COFFIN and Lieut. PAGE in the years 1845 and 1846. The results from different stars are given in the following table.

No. Observ'ns	Star	φ	Weight
195	*Polaris*	$+38^\circ\ 53'\ 39''.52$	10
17	δ *Urs. Min.*	39.04	3
19	α *Urs. Maj.*	38.59	4
8	ζ *Urs. Min.*	38.49	2
11	λ *Urs. Min.*	39.41	2
7	α *Cephei*	39.75	1
12	β *Cephei*	38.90	2
41	γ *Cephei*	$+38\ 53\ 39.62$	4

By weight, therefore, the result is

$$\varphi = +38^\circ\ 53'\ 39''.23$$

The latitude finally adopted, and which was used in all reductions until 1866, was

$$+38^\circ\ 53'\ 39''.25$$

In 1861 Professor NEWCOMB began a series of observations with the Mural Circle for a new determination of the latitude, and these observations were continued through the years 1862, 1863 and 1864. In the last year many observations were made by reflexion, thus bringing to bear on the latitude different parts of the circle, and tending to eliminate errors of graduation and flexure. The result is the second value given above; and it is curious to notice that in this determination the three pole stars, *Polaris*, δ *Urs. Min.* and λ *Urs. Min.*, used by the first observers, give the very consistent correction of —0″.31 to the first latitude. This second value was adopted for use on the Transit-Circle in 1866, and has become the standard latitude of the Naval Observatory.

The third value is the mean result of observations with the Pistor and Martins Transit-Circle during the years 1866 to 1884, excluding the result for 1880, which appears to be erroneous. The data for the preceding values will be found in the annual volumes of the Naval Observatory.

In 1883 I made a determination of the latitude with one of the portable instruments of the Transit of *Venus* Commission. The optical power of this instrument was less than that of the Mural and Transit-Circles, but on the other hand a result by TALCOTT's method depends chiefly on the declinations of the stars, and appears to be free from some of the errors that may vitiate the most careful observations with large fixed instruments. This result was found from 130 observations of 42 pairs of stars, and the value of the latitude is

$$1883, \quad \varphi = +38° \; 53' \; 38''.94 \pm 0''.061$$

(*Astr. Nachr.* no. 2625).

There is another method of examining this question from the early observations of the Observatory. In 1845 observations were begun with the Prime Vertical Transit, and a sufficient number of observations of *α Lyrae* were made in that year, so that by assuming a declination of the star we may compute the latitude of this instrument. The observations are so well distributed that any parallax of the star would be nearly eliminated in the mean result for the year. There are 62 observations of this star in 1845, of which 41 were made by the Superintendent, Lieut. MAURY, 20 by Lieut. HERNDON, and one by Lieut. WORDEN. The instrument was placed in charge of Professor HUBBARD in 1848, who made the observations of that year. The work on this instrument was then nearly discontinued until 1862, when it was revived by Professor HUBBARD, and observations of *α Lyrae* were made during five years. In 1845 and 1848 the observers were inexperienced, and the probable errors of a single observation were respectively ±0″.34, and ±0″.33. In the later years the probable error of a declination was ±0″.19. The declination and proper motion of this star are well known. I have taken the position of the star from the catalogue of Professor BOSS, and by means of his precession and proper motion have carried back the declination to the epochs to which the observations are reduced, 1845, 1850, 1860, and 1870; and compared them with those found with the Prime Vertical Transit. In deducing the declinations from the observations a latitude was assumed, and the declination was computed from STRUVE's formula,

$$\tan\delta = \tan\varphi \cos s \cos u$$

If the declination be known, therefore, we may find the correction of the assumed latitude; and in the case of *α Lyrae* this is easily done, since this star passing only a quarter of a degree south of our zenith the changes in δ and φ are nearly the same. The following table gives the result of this comparison. In 1845 the assumed latitude of the Prime Vertical instrument was +38° 53′ 39″.00; and in the other years +38° 53′ 38″.80. The reduction from the Prime Vertical to the center of the Observatory is +0″.45. The quantities will be understood from the headings of the columns, φ' giving the seconds of latitude for the instrument, and φ the latitude of the Observatory.

Date	No. Obs.	Observed δ	Comp δ	Diff.	φ'	φ
		° ′ ″	″	″	″	° ′ ″
1845	62	+38 38 34.80	33.75	—1.05	37.93	+38 53 38.38
1848	71	38 50.43	48.97	—1.46	37.31	37.76
1862	93	39 20.23	19.62	—0.61	38.18	38.63
1863	71	20.22	19.62	—0.60	38.19	38.64
1864	90	20.24	19.62	—0.62	38.17	38.62
1865	76	39 51.22	50.57	—0.63	38.16	38.61
1866	90	+38 39 51.28	50.57	—0.71	38.08	+38 53 38.53

Although there may be a small error in the assumed declination of the star, which would make the resulting latitudes erroneous, yet the position of this star and its motion in declination are so well known that the relative values of the latitude cannot be much in error.

If now we consider the whole of the preceding results, it is evident that there is no proof of a secular change in the latitude. These results show, moreover, that the absolute determinations of latitude are subject to small errors which require the utmost care on the part of the observer if they are to be avoided. It will be seen that this is the case even with the Prime Vertical instrument, where the results do not depend on a graduated circle. In the case of the Mural Circle, where six microscopes were read, it was assumed as probable that the mean reading would be to a large extent free of errors of graduation and flexure of the circle, but this is a point that should be examined. Another doubtful point, I think, is the reading of the external thermometer, especially during the early parts of the night when the walls of the building were radiating heat.

Naval Observatory, 1890 *July* 16.

OBSERVED MAXIMA AND MINIMA OF *T* AND *U MONOCEROTIS*, IN 1889–90.

BY PAUL S. YENDELL.

T Monocerotis.

Sixty-six observations of *T Monocerotis*, from 1889 Nov. 5 to 1890 April 25, yield six maxima and six minima, as follows:

MAXIMA

	w	
1889 Nov. 30.4	4	by single curve
Dec. 25.4	1	by mean curve
1890 Jan. 21.6	5	by single curve
Feb. 16.4	4	by mean curve
Mar. 17.1	4	by single curve
Apr. 14.4	4	by single curve

MINIMA

	w	
1889 Nov. 21.0	4	by single curve
Dec. 18.5	4	by single curve

MINIMA

		w	
1890 Jan.	13.4	3	by single curve
Feb.	5.9	3	by mean curve
1890 Mar.	6.4	2	by mean curve
	30.5	3	by mean curve

The mean light-curve used in these reductions is the same as that used in reducing the previous season's observations, and is formed from the observations of 1888 and 1889.

Dorchester, Mass., 1890 *July* 23.

U Monocerotis.

Between 1889 Nov. 28 and 1890 April 25, this star was observed forty-nine times. When first observed, on Nov. 28, its magnitude was estimated at $7^M.0$, it rose to a maximum of $6^M.5$ on Dec. 17; other maxima were observed as follows: 1890 Feb. 12, $6^M.45$, and an ill-defined one of $6^M.6$ on April 10; only one definite minimum was observed, on Mar. 9, at which time its observed magnitude was $7^M.45$.

ON THE COMPUTATION OF PROBABLE ERRORS.

BY WILLIAM HARKNESS.

The following formulas may not be new, but as I have never seen them in the course of my reading, and as their use will frequently abbreviate one of the most tedious processes in the method of least squares, I venture to publish them.

Imagine a function of which we have n observed values, given in the form $f + \delta f$, $f + \delta f'$, $f + \delta f''$, etc.; and let the mean of δf, $\delta f'$, $\delta f''$, etc., be δf_0. Then, if f_0 is the true value of the function, we shall have

$$f_0 = f + \delta f_0$$

To find the probable error of f_0 we must compare it with each of the observed values, and thus we shall obtain a series of residuals which may be written

$$v = \delta f - \delta f_0 \quad v' = \delta f' - \delta f_0 \quad v'' = \delta f'' - \delta f_0 \quad \text{etc.}$$

We require the sum of these residuals taken without regard to sign, and in order to find it we divide them into three classes. Thus:

(a). When δf and δf_0 have the same sign, and δf is numerically greater than δf_0

$$v = \delta f - \delta f_0$$

(b). When δf and δf_0 have the same sign, and δf is numerically smaller than δf_0

$$v = \delta f_0 - \delta f$$

(c). When δf and δf_0 have opposite signs

$$v = \delta f + \delta f_0$$

Now regarding the v s, the δf s, and δf_0 as essentially positive, let there be m_1 residuals of class (a), m_2 of class (b), and m_3 of class (c); let their sums be respectively $[v]_1$, $[v]_2$, $[v]_3$; and let the corresponding sums of the δf s be $[\delta f]_1$, $[\delta f]_2$, $[\delta f]_3$. Then (1)

$$[v]_1 + [v]_2 + [v]_3 = [\delta f]_1 - [\delta f]_2 + [\delta f]_3 - (m_1 - m_2 - m_3)\,\delta f_0$$

and as

$$[v] = [v]_1 + [v]_2 + [v]_3$$
$$[\delta f] = [\delta f]_1 + [\delta f]_2 + [\delta f]_3$$

this reduces to

$$(2) \qquad [v] = [\delta f] - 2[\delta f]_2 - (m_1 - m_2 - m_3)\,\delta f_0$$

Washington, D.C., 1890 *Aug.* 1.

Finally, by Dr. C. A. F. PETERS's formula, the probable error of any one of the values of $f + \delta f$ is

$$r = \frac{0.8453\,[v]}{\sqrt{[m(m-1)]}} \qquad (3)$$

and the probable error of f_0 is

$$r_0 = \frac{r}{\sqrt{m}} = \frac{0.8453\,[v]}{\sqrt{(m^3 - m^2)}} \qquad (4)$$

As formula (2) obviates the necessity for computing the individual v s, it greatly reduces both the numerical work and the risk of error. As an example of its use, take the following numbers which occurred in a computation relating to the moon's mass, and let it be required to find their mean, and its probable error.

+194	+ 90	+ 81
− 26	+287	− 88
+207	− 42	+ 35
+ 6	− 16	−116
−103	−217	− 18
+238	+145	+ 32
+260	−172	+ 2
+172	−183	+ 84
− 60	−129	+ 51
− 62	+ 78	−275
		+201

The entire computation is as follows:

$$m_1 = 15, \qquad \delta f_0 = (+2169 - 1507)/31 = +21.4$$
$$m_2 = 2, \qquad [\delta f] = 2169 + 1507 = 3676$$
$$m_3 = 14, \qquad 2[\delta f]_2 = 16$$
$$(m_1 - m_2 - m_3)\,\delta f_0 = -21$$
$$[v] = 3681$$

Then by formula (4) $\qquad r_0 = \pm 18.33$

and finally

$$\delta f_0 = +21.4 \pm 18.3$$

The little instrument known as Webb's Adder greatly facilitates the formation of $[\delta f]_1$, $[\delta f]_2$, etc., because by its aid quantities scattered throughout a column of figures can be selected and added with rapidity and accuracy.

THE AUGUST PERSEIDS, 1890,

BY EDWIN F. SAWYER.

The observations of this annual meteor-shower were confined this year to the evenings between August 3 to 8, the dates of its maximum display, 9 to 11, being unfortunately overcast. Owing to the moon's early rising the observations were necessarily limited in duration; and the number of meteors recorded less numerous than would have been the case, could a later hour have been selected, and a longer watch maintained. However, of the 40 meteors recorded, 22 were observed with sufficient accuracy to allow their paths being correctly mapped. From the best paths mapped on the 6th and 8th, the radiant point was fairly well determined as at R.A. 44°, Decl. +57°. The following table gives the dates of observation, number of meteors recorded, etc.:

August	Duration of Watch			Length of Watch	Magnitude					Total	Perseids
					$>1^{M}$	$=1^{M}$	$=2^{M}$	$=3^{M}$	$=4^{M}<$		
	h m		h m	h m							
3	8 35	to	9 35	1 0	0	0	0	1	3	4	2
4	8 55	to	9 55	1 0	0	1	0	1	5	7	2
5	8 35	to	9 55	1 20	1	0	1	2	6	10	3
6	8 45	to	9 15	0 30	1	0	1	0	3	5	2
8	8 40	to	10 30	1 50	1	2	3	2	6	14	10
				5 40	3	3	5	6	23	40	19

METEOR TRACKS MAPPED.

No.	Date 1890	Camb. M.T.	Mag.	Observed Path				Length of Path	Wt.	Remarks
				From		To				
				R.A.	Decl.	R.A.	Decl.			
		h m		°	°	°	°	°		
1	Aug. 3	8 55	5	345	+82½	272½	+79	7	3	Perseid
2	" "	9 6	3	319½	+64½	282½	+42	28	3	From *α Cephei* to near *α Lyrae*; perseid
3	" 4	9 22	3	2	+78	60	+80	8	3	
4	" "	9 33	6	342½	+58	332½	+56½	6	3	Short and rapid
5	" "	9 50	1	190	+55	196½	+40	13	4	Streak 2 seconds; perseid
6	" "	10 3	5	339	+62½	340	+55	7	3	
7	" 5	8 40	4	1	+58½	347½	+57	7	4	From *β Cassiopeae*; perseid
8	" "	8 45	5	325	+55	331½	+57½	4	3	Short and rapid
9	" "	8 59	>1	240	+80	227½	+64	15	4	Streak 2 seconds; perseid
10	" "	9 13	6	317½	+69¾	320	+70	1	3	Very short path
11	" "	9 35	2	287½	+68	260	+62	12	4	Streak 1 second
12	" "	9 36	4	285	+67½	287	+67	½	3	Nearly stationary
13	" "	9 55	3	21	+85	210	+85	7	4	Across *Polaris*
14	" 6	8 55	4	340	+58½	330	+56	6	4	Across *δ Cephei*; perseid
15	" "	9 0	6	355	+72½	10	+72¾	5	3	Short and rapid
16	" "	9 7	. . .	199	+16	192	+13	. . .	2	Very brilliant pear-shaped fire ball 1/3 diameter of moon; visible 3 seconds; fell nearly on a line with *Alpha* and *Eta Bootis*. Attention first attracted by a brilliant light in southwest, and turned in time to see its disappearance behind some trees; no streak left; path approximate. Seen at various places in Mass. and N.H. Said to have fallen at Keene, N.H. — *Boston Herald*, Aug. 8.
17	" 8	8 43	2	330	+84	97½	+80	11	4	
18	" "	8 46	5	330	+57½	316	+52	9	3	Perseid
19	" "	8 47	5	310	+70	309	+72½	3	3	Very short and rapid
20	" "	9 34	1	260	+76	242½	+54	20	4	Streak 2 seconds; perseid
21	" "	9 38	>1	45	+65	40	+75	9	3	Perseid
22	" "	10 20	2	255	+70	247½	+57	13	3	Streak 1 second; perseid

Brighton, Mass., 1890 *August* 13.

ON GORE'S NEW VARIABLE, IN *HERCULES*.

BY PAUL S. YENDELL.

The variability of this star, which is no. 367 of BIRMINGHAM's Catalogue = DM. 47° 2291, has recently been announced by Mr. GORE in no. 2981 of the *Astronomische Nachrichten*.

At his request, I began observations upon it in November, 1889, and observed the star a few times, but it was already so low in the northwest that the reflection from the electric lights of the city rendered observation difficult and uncertain, and no definite conclusion as to its variability could be arrived at from the few observations secured.

The watch on the star was resumed in April, 1890, and from April 15 to August 16, thirty-three observations have been made, which definitely establish the fact of the star's variation; a not very sharply marked minimum is shown on May 13.5, followed on June 26.0 by a maximum, quite definitely indicated by the observations; the decrease in light was rather slow and fluctuating, and it is now again apparently just at or past a minimum, indicating a period of about three months.

The star's minimum light appears to be about $7^M.1$ or $7^M.2$; at the maximum lately past, it reached about five or six steps higher, equivalent to six or eight-tenths of a magnitude; but from statements made to me by Mr. Gore in a private letter, it seems probable that the star's light differs considerably at different maxima, and that the last one was rather faint.

The comparison-stars used, with the light-scale formed from the observations, are as follows:

	M — DM.	Light	M — Y
b = DM. +47° 2300	6.7	15.0	6.0
a = DM. +47° 2288	7.0	5.0	7.2

The interval of ten steps, shown by the observations, indicates a difference of about $1^M.25$ between the two stars, and it seems probable that either one or both the stars have changed in light since the DM. estimates were made, as comparisons with neighboring stars indicate that b is now about $6^M.0$, while a appears to my eye rather faint for a $7^M.0$; the estimates of magnitude arrived at by me are therefore given in the right-hand column of the above table.

The observations obtained this year, with the observed light by the above scale, are as follows:

Camb. M.T.	Light	Camb. M.T.	Light
1890 Apr. 15.365	6.5	1890 July 6.405	9.0
16.385	7.0*	8.427	8.5
20.351	7.0	9.422	8.5
May 2.378	7.5	11.398	8.0
11.395	6.0	13.375	8.0
16.392	6.0	16.420	9.0
18.365	6.0	17.407	8.0
21.414	7.0	19.430	8.0
June 8.382	7.5	21.395	7.5*
9.420	8.0	27.379	7.5*
14.411	9.0	Aug. 2.365	7.0*
15.417	9.0	4.382	6.5
18.399	10.0	6.392	6.0
20.385	9.75	13.399	5.5
28.378	10.75*	15.540	6.5
30.424	9.75*	16.375	6.0
July 5.427	9.75		

* Moonlight.

Dorchester, Mass., 1890 *August* 16.

ELEMENTS OF COMET c 1890 (*DENNING*).

BY ARMIN O. LEUSCHNER.

From Mr. Barnard's observations of July 25, Aug. 3, and Aug. 9, I have deduced the following elements of Comet c 1890 (Denning):

$$T = 1890 \text{ Sept. } 24.4824 \text{ G.M.T.}$$

$$\left.\begin{aligned} \omega &= 162^\circ\ 45'\ 59''.9 \\ \Omega &= \ \ 99\ \ \ 56\ \ \ 27\ .9 \\ i &= \ \ 98\ \ \ 58\ \ \ 25\ .8 \end{aligned}\right\} \text{M. Eq. } 1890.0$$

$$\log q = 0.101606$$

$$\text{O}-\text{C}, \quad d\lambda \cos\beta = +9''.5, \quad d\beta = +5''.2.$$

$$x = 9.465412 \sin(111^\circ\ 26'\ \ 5''.7 + v) \sec^2 \tfrac{1}{2} v.$$
$$y = 0.090981 \sin(274\ \ \ 56\ \ \ 56\ .1 + v) \sec^2 \tfrac{1}{2} v.$$
$$z = 0.100374 \sin(185\ \ \ 55\ \ \ \ 0\ .8 + v) \sec^2 \tfrac{1}{2} v.$$

Lick Observatory, 1890 *Aug.* 14.

FILAR-MICROMETER OBSERVATIONS OF COMETS b AND c 1890,

MADE AT THE DUDLEY OBSERVATORY.

BY LEWIS BOSS.

1890 Albany M.T.	✱	No. Comp.	☄ — ✱ $\Delta\alpha$	☄ — ✱ $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log p Δ	
				Comet a (Coggia).				
Aug. 4ᵈ 8ʰ 58ᵐ 58ˢ	1	6 , 2	−4ᵐ 5ˢ.96	+1′ 58″.9	10 31 39.36	+30 24 20.4	9.674	0.799
				Comet c (Denning).				
Aug. 7 10 14 56	2	4 , 2	−0 26.40	−2 45.3	15 18 7.30	+61 38 21.9	9.847	8.549
15 9 56 48	3	15 , 5	−4 27.69	−0 8.3	15 23 47.36	+50 34 15.6	9.699	0.472

Mean Places for 1890.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	10 35 45.66	—0.34	+30 22 16.6	+ 4.9	Leiden A.G. Zones
2	15 18 32.88	+0.82	+61 40 52.2	+15.0	Krueger's A.G. Zones
3	15 28 11.37	+0.68	+50 31 41.8	+12.1	Oe. Arg. 15150

NOTES.

The comet of Coggia was barely visible through light fog when observed on August 4.

The observation of Comet *c* was extremely difficult on August 7, owing to the prevalence of thin clouds. The comparison-star No. 2 is found in Krueger's zones, 233 and 387, but in the former its R.A. for 1875.0 is given as 21s.03, while in the latter it is given as 15s.17. This star is Radcliffe (1845) 3374, and the R.A. from that authority decides for the correctness of Krueger's zone 387.

The difference, Oe. Arg. 15450 — Oe. Arg. 15475, as measured by me is: $\Delta\alpha = -1^m\ 55^s.88$: $\Delta\delta = +3''.9$. The position of star No. 3 is adopted from the mean between the catalogue-position and that derived through Oe. Arg. 15475.

OBSERVATIONS OF COMET *a* 1890 (*BROOKS*),

MADE AT THE U.S. NAVAL OBSERVATORY WITH THE 9.6-INCH EQUATORIAL,

By Prof. E. FRISBY.

[Communicated by the Superintendent.]

1890 Washington M.T	*	No. Comp.	☄ — * Δα	☄ — * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
d h m s			m s	′ ″	h m s	° ′ ″		
Aug. 15 9 6 12	1	10 , 2	+4 2.17	—2 26.0	13 2 16.30	+40 11 28.0	9.777	0.587
15 9 6 12	2	10 , 2	+1 33.73	—0 11.8	13 2 16.62	+40 11 28.6		
16 9 5 13	3	20 , 4	+2 21.62	—3 20.2	13 1 56.20	+39 51 37.2	9.776	0.589

Mean Places for 1890.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	12 58 14.16	—0.03	+40 13 45.4	+8.6	Bonn VI, 39° 2613
2	13 0 42.91	—0.02	+40 11 31.8	+8.6	Radcliffe 2957
3	12 59 34.62	—0.04	+39 54 49.0	+8.4	Weisse's Bessel (2) XII, 1141

OBSERVATIONS OF *EUCHARIS* (181),

MADE AT THE U.S. NAVAL OBSERVATORY,

By A. HALL.

[Communicated by Capt. F. V. McNair, U. S. Navy, Superintendent.]

1890 Washington M.T.	*	No. Comp.	⊙ — * Δα	⊙ — * Δδ	⊙'s apparent α	⊙'s apparent δ	log pΔ for α	log pΔ for δ
d h m s			m s	′ ″	h m s	° ′ ″		
May 15 10 58 37.9	1	20 , 5	—2 2.97	+1 58.8	15 24 19.40	+7 52 3.4	*n*9.003	0.656
17 10 24 39.3	2	20 , 5	+1 54.98	+1 32.3	15 22 52.12	+7 55 47.7	*n*9.172	0.658
18 9 21 6.9	2	20 , 5	+1 13.00	+3 4.5	15 22 10.15	+7 57 20.1	*n*9.407	0.668
21 10 55 44.7	3	20 , 5	+1 50.53	—1 3.8	15 19 57.51	+8 1 7.8	*n*8.706	0.652

Mean Places for 1890.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	15 26 21.01	+1.36	+7 50 9.6	−5.0	DM. +7° 2971; ½(Paris + Wash.)
2	15 20 55.78	(+1.36) (+1.37)	+7 54 20.0	(−4.6) (−4.4)	DM. +8° 3030; ½(Paris + Wash.)
3	15 18 5.58	+1.40	+8 2 15.6	−4.0	DM. +8° 3020; ½(Paris + Wash.)

NOTE. — These observations were made at the request of Dr. L. DE BALL, for his work on the mass of *Jupiter*. Since two of the stars of comparison are of the 9.5 magnitude, and do not appear in any accurate catalogue, it may be well to give the positions observed at Paris and Washington.

	α 1890.0	δ 1890.0		No. Obs.
	h m s	° ′ ″		
DM. +7.2971;	15 26 20.97	+7 50 9.7	Paris	(3.2)
	21.05	9.6	Washington	(3.3)
DM. +8.3030;	15 20 55.69	+7 54 20.4	Paris	(3.2)
	55.86	19.6	Washington	(3.4)
DM. +8.3020;	15 18 5.56	+8 2 15.4	Paris	(3.3)
	5.60	15.8	Washington	(5.5)

1890 *August* 20.

OBSERVATIONS OF COMET *a* 1890 (BROOKS),

WITH THE TRANSIT-CIRCLE AT THE U.S.N. OBSERVATORY.

[Communicated by the Superintendent.]

Date	Observer	R. A.	N. P. D.
1890		h m s	° ′ ″
June 19	Eastman	16 18 9.78	21 21 40.6
23	Eastman	15 38 42.51	25 14 3.2
24	Skinner	29 43.53	25 33 21.9
25	Eastman	21 7.88	25 54 41.7
26	Skinner	12 56.22	26 17 59.6
27	Eastman	15 5 7.51	26 12 18.5
28	Skinner	14 57 42.70	27 13 13.8

The positions depend upon the stars of the Berlin Ephemeris, and are uncorrected for parallax

OBSERVED MAXIMUM OF *R HYDRAE*, 1890,

BY EDWIN F. SAWYER.

This interesting variable has recently passed through another maximum. Observations were began on April 11, and terminated on June 16. When first seen on April 11, *R* was 1 steps > 352 (*U.A.*) *Hydrae*, and 5 steps < 355 (*U.A.*) *Hydrae*, or $6^{M}.8$. The increase of light was very rapid and uniform, a maximum being reached May 25.5. The maximum brightness was 5 + steps > 131 (*U.A.*) *Virginis* = 31 (*U.A.*) *Corvi*, and 5 steps < 9 (*U.A.*) *Corvi*, or $4^{M}.6$. The light at maximum appeared constant from May 11 to June 9, a period of 29 days. Owing to the star's approach to the sunset horizon it could not be followed after June 16, on which date, however, it had faded some 3 or 4 steps to about $4^{M}.9$.

OBSERVATIONS.

	M		M		M		M		M		M
Apr. 11	6.8	Apr. 25	5.85	June 8	4.6	Apr. 19	6.2	May 11	4.6	June 15	4.9
15	6.5	28	5.5	9	4.6	20	6.1	21	4.6	16	4.9

COMPARISON-STARS USED.

			1875.0 α	1875.0 δ	Magnitude Gould	Magnitude Sawyer
9	(*U.A.*)	*Corvi*	= 12 1 58	− 24 1.9	4.2	4.2
31	"	*Corvi*	= 12 25 40	− 15 30.1	4.5	4.65
131	"	*Virginis*	= 13 11 52	− 17 36.9	5.3	5.0
341	"	*Hydrae*	= 13 2 19	− 22 26.9	5.3	5.35
124	"	*Virginis*	= 13 9 13	− 19 16.6	5.7	5.6
120	"	*Virginis*	= 13 7 30	− 19 16.5	5.8	5.65
135	"	*Virginis*	= 13 14 17	− 18 50.0	6.1	6.4
355	"	*Hydrae*	= 13 31 37	− 22 19.0	6.6	6.6
352	"	*Hydrae*	= 13 30 18	− 22 58.5	7.0	6.85

Brighton, Mass., 1890 *August* 15.

NEW ASTEROIDS.

A planet of the 13th magnitude was discovered by **Palisa**, at Vienna, in the position
Aug. 17.50 Gr. M.T. $\alpha = 23^h\ 0^m\ 28^s$, $\delta = -2°\ 24'$. Daily motion, -40^s in α, and 3′ southward.

A planet of the 13th magnitude was discovered by **Charlois**, at **Nice**, August 19. Its position was:
Aug. 21.4719 Gr. M.T. $\alpha = 22^h\ 19^m\ 54^s.4$, $\delta = -12°\ 20'\ 24''$. Daily motion, $-13'$ in α, and 6′ southward.
These are probably Nos. 295 and 296.

NEW ASTRONOMICAL WORKS.

Catalogue of 8241 Stars between 0° 50′ and 5° 10′ of north declination (1855) for the Epoch 1875, deduced according to the Programme of the Astronomische Gesellschaft, at the Dudley Observatory of Albany, by **Lewis Boss**. Published by the *Astronomische Gesellschaft*, Leipzig, 1890.

On the title-page this work is denoted: *Catalog der Astronomischen Gesellschaft, Erste Abtheilung, Vierzehntes Stück.* The present catalogue contains for the Albany Zone, results obtained under the well known programme of the *Astronomische Gesellschaft*, formulated more than twenty years ago.

The instrument employed was the Pistor and Martins Circle of the Albany Observatory (telescope 8-in. aperture). The position of each star in the catalogue depends upon at least two observations in each coordinate; and for nearly all stars supposed to be brighter than $8^M.0$ the number of observations is three or more. The catalogue contains several hundred stars in addition to those of the programme. The probable error of a single observation is given as $\pm 0^s.036$ and $\pm 0''.55$ for R.A. and Decl. respectively. Special investigations indicate that the published catalogue-positions require the correction:

$$-0^s.0087\ (M-4) - 0^s.00106\ (M-4)^2$$

in which M denotes the magnitude of the star observed.

The observations are strictly differential, and are based upon the standard positions of *Publ.* XIV *der Astr. Ges.* The history of the work and methods of observation and computation are set forth in the Introduction, which contains also a "Register of Zones," giving, for each zone, the date and most noteworthy general features of observation. The Introduction also summarizes the results of a comparison of the Albany determinations with those of **Bradley**, **D'Agelet**, **Piazzi**, **Lalande** (Zones), **Bessel** (Zones), **Struve**, **Römker** and **Schjellerup**. The detailed results of these comparisons are contained in special tables following the catalogue proper.

In Part I of the *Notes to the Catalogue* is presented the discussion of 422 stars for proper motion, and other suspected motions are alluded to in the final notes.

The arrangement of the catalogue proper is explained at the end of the Introduction, and at the foot of each page are given short notes relating to anomalies in estimates of magnitude, or among observed positions, estimates of position-angle and distance for double-stars noticed during observation, and to other matters, while longer notes are to be found at the end of the catalogue.

Catalog von 14680 Sternen zwischen 54° 55′ und 65° 10′ nördlicher Declination 1855, für das Aequinoctium 1875, nach Beobachtungen um 8-füssiger Reichenbach'schen Passagen-instrument der Helsingforser Sternwarte, auf der Sternwarte der Universital Helsingfors in den Jahren 1869 bis 1876 und auf der Herzoglichen Sternwarte zu Gotha in den Jahren 1877 bis 1880, von **A. Krueger**. *Herausgegeben von der Astronomischen Gesellschaft.* Leipzig, 1890.

This work is designated: *Catalog der Astronomischen Gesellschaft, Erste Abtheilung, Viertes Stück.* The observations upon which it depends were the earliest published of the great international series of which they form a part; and this corresponding catalogue is the second in order; this and that of Prof. Boss being distributed together.

The removal of Prof. **Krueger** from Helsingfors to Gotha in 1876, while it entailed a change of latitude for the observer, did not require any change of instrument, and does not appear to have impaired, in the least, the unity of the system of observations. The instrument which he had used at Helsingfors was transferred to Gotha, whence it was returned to its old position in 1881, and used there for filling out a few incomplete observations.

The transit-instrument has an aperture of 66 Paris lines (149 *mm*), and was equipped with an auxiliary arc, of 15 inches radius, the divisions of which were elaborately studied, as well as with a slow-motion apparatus for declination. All the transits were observed by the method of eye-and-ear.

Prof **Krueger** has determined the probable error of a single observation as $\pm 0^s.101$ and $\pm 0''.51$ at Helsingfors, and as $\pm 0^s.125$ and $\pm 0''.76$ at Gotha, for a mean declination of 60° and 3 or 4 threads. These values include the effect of any uncertainty in the determining stars; and would moreover be considerably reduced by special discussion of some of the individual zones. He has, furthermore, convinced himself that the brightness of the star produced no essential effect upon the observed time of transit.

All the stars in the *Durchmusterung*, to the magitude $9^M.1$ inclusive, were placed upon the working-list, and all these, with few exceptions, were observed. So, too, were all those stars for which an appended letter in the DM. showed that earlier observations existed. A list of the omitted stars, which fall within these categories is given in the Introduction; also a special list of the 43 stars observed in the cluster *h Persei*; and, furthermore, a table for correcting the secular variations on account of proper motion, for 258 stars, for which alone this effect is appreciable.

Prefixed to the catalogue is a table for computing the third term in the precessions, with arguments at intervals of 10^m in right-ascension, and of single degrees in declination. All known proper motions of the stars in the catalogue are given in the notes

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New Asteroids.
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SUPPLEMENT TO "SECULAR AND LONG-PERIOD INEQUALITIES IN THE MOON'S MOTION."

BY JOHN N. STOCKWELL.

In numbers 220 and 221 of this *Journal* I have given an investigation of the secular inequalities in the motion of the moon's perigee; and have obtained a result differing largely from the values found by previous investigators. I have also applied the value there found to the discussion of the most celebrated solar eclipses of ancient times, and have obtained results which correspond well with the historical narratives of the same events which have been preserved to our times. The purpose of this supplement is to exhibit the effect of this theoretical change in the motion of perigee upon the accurate observations of modern times.

The general effect of the change thus introduced was briefly stated in the previous investigation; and it now only remains to determine the actual value of the corrections to the moon's longitude thus arising, at certain specified times and places of the moon in her orbit. On account of the very slow changes in the element referred to, it is not necessary to compute the resulting effects on the moon's longitude for very short intervals of time; and I have given in the accompanying table, the values of the corrections to the moon's longitude as derived from Hansen's *Tables de la Lune*, for four points of the moon's orbit at intervals of *one hundred anomalistic revolutions of the moon*, which amounts to about 7.544 years. The four points of the orbit to which the corrections given in the table apply, correspond to the respective mean anomalies of 0°, 90°, 180° and 270°; and the dates to which the last three mentioned anomalies correspond, may be found by adding a period of *one-fourth*, *one-half* and *three-fourths* of an anomalistic revolution to the date given in the first column of the table, which corresponds to the mean anomaly 0°. In the table, columns 2 to 5 give the whole correction arising from the change in the motion of the perigee. Column 6 gives the correction due to the change in the secular equation of the mean longitude; while columns 7 to 10 give the whole change in the longitude arising from both causes. The table covers a period of 256 years, or from the year 1650 to the year 1906, and is amply sufficient for showing the effect of the theoretical changes in the lunar elements upon the moon's calculated place in modern times.

In this connection it may not be amiss to call attention to a notice of the subject under discussion which appeared in the August number of *The Observatory*. The writer of the notice, Mr. W. T. Lynn, indulges in some criticisms which do not appear to me to be well founded, and to these I wish to briefly call attention.

In speaking of the eclipse of Thales, Mr. Lynn remarks: "The narrative in Herodotus seems to imply that the battle which was stopped by the eclipse took place whilst Cyaxares still reigned over Media . . . ." Now I am unable to see that any inference at all is *implied* in the narrative of Herodotus. In his narrative concerning the eclipse he explicitly states that Cyaxares was reigning: and later in his history, Art. 103, he says "It was he (Cyaxares) that fought with the Lydians, when the day was turned into night as they were fighting; and who subjected the whole of Asia above the river Halys."

Pliny's allusion to the eclipse seems to have been made for an entirely different purpose than the fixing the date of the eclipse. The chapter of his work in which it occurs is devoted to an account of the discoveries which had previously been made in astronomy; and among these discoveries was the art of predicting eclipses. Now, notwithstanding the fact that Herodotus and Pliny perfectly agree in regard to the prediction of the eclipse by Thales, Mr. Lynn feels justified in rejecting that fact, for the simple reason that he is unacquainted with the method by which the prediction was made. And yet he presumes to decide in favor of the date which Pliny incidentally gives, notwithstanding the fact that he (Pliny) lived at an epoch more than *five hundred years* later than Herodotus, and his sources of information were probably much less reliable.

In regard to the eclipse which was seen at Sardis while Xerxes was on the way to Greece, and which occurred in the same year in which the battle of Salamis was fought, I am aware that it has long been a subject of controversy.

simply for the reason that astronomers have been unable to find any solar eclipse whatever visible at Sardis about that time. And the single fact that my corrections to the elements of the moon's motion are such as to cause an eclipse at Sardis, which satisfies all the historical traditions concerning the event, is of vast importance, not only as a great triumph of science, but also as an interesting verification of the statements of the historian. For THUCYDIDES tells us that the Persian invasion of Greece by XERXES preceded the beginning of the Peloponnesian war by fifty years; and the eclipses of XERXES and PERICLES confirm the statement of the historian in the most satisfactory manner. It therefore follows that the Persian war occurred one year earlier than has been heretofore supposed by modern historians.

Lastly, a word in regard to the eclipse of HOMER. Mr. LYNN calls attention to the fact that the darkness enshrouded only those who were contending for the body of PATROCLUS. But this is simply quoting HOMER against HOMER: for the poet tells us a little later, when it was proposed to inform ACHILLES of the death of PATROCLUS, the Greeks were unable to find a suitable messenger for the purpose because the *whole field* was enveloped in darkness. It is moreover hardly to be expected that all the poetic details of the occasion are given with sufficient precision and clearness to satisfy a prosecuting attorney; but nevertheless, the main fact, that a sudden and unusual darkness enveloped the whole field of battle remains undisputed.

TABLE SHOWING THE CORRECTIONS TO THE MOON'S LONGITUDE AS GIVEN BY HANSEN'S TABLES, ARISING FROM THE CHANGES IN THE SECULAR EQUATION OF THE MEAN MOTION, AND IN THE MOTION OF THE PERIGEE.

Date	Terms of Δv depending on Δω				Secular Terms of Δv	Complete values of Δv			
	Mean Anomalies					Mean Anomalies			
	0°	90°	180°	270°		0	90°	180°	270°
	″	″	″	″	″	″	″	″	″
1650.150	— 1.00	+0.04	+ 0.89	+0.13	—9.32	—10.32	—9.27	— 8.43	—9.19
57.694	— 0.11	—0.01	+ 0.09	+0.01	8.41	8.52	8.42	8.32	8.40
65.238	+ 0.51	—0.13	— 0.48	+0.05	7.55	7.04	7.68	8.03	7.50
72.782	1.23	+0.10	1.02	—0.27	6.73	5.50	6.63	7.75	7.00
80.326	1.88	—0.18	1.11	+0.09	5.96	4.08	6.14	7.08	5.88
87.870	2.22	—0.30	2.13	—0.11	5.21	3.02	5.54	7.37	5.35
1695.414	2.30	+0.18	1.83	—0.47	4.56	2.26	4.38	2.74	5.04
1702.958	2.38	—0.64	2.24	+0.34	3.94	— 1.55	4.57	6.18	3.60
10.502	3.41	+0.06	2.94	—0.60	3.35	+ 0.05	3.29	6.30	3.96
18.046	2.52	—0.04	3.21	—0.11	2.82	— 0.30	2.85	6.03	2.93
25.590	3.31	—0.70	3.12	+0.13	2.33	+ 0.98	3.03	5.45	2.20
33.134	3.33	+0.38	2.69	—0.77	1.89	1.45	1.50	4.58	2.66
40.678	2.53	—0.55	2.29	+0.32	1.49	1.04	2.04	3.78	1.17
48.222	3.44	—0.23	3.09	—0.37	1.14	2.30	1.37	4.23	1.51
55.766	2.44	+0.20	1.94	—0.37	0.84	1.60	0.64	2.78	1.20
63.310	2.35	—0.62	2.23	+0.26	0.58	1.77	1.20	2.81	0.32
70.854	2.40	+0.16	2.01	—0.51	0.37	2.03	0.21	2.39	0.88
78.398	1.36	—0.15	1.16	+0.06	0.21	1.15	0.36	1.37	0.15
85.942	1.34	—0.20	1.24	—0.03	0.09	1.25	—0.30	1.33	0.13
1793.186	+ 0.63	+0.08	— 0.50	—0.13	0.02	+0.60	+0.05	— 0.52	—0.16
1801.031	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.575	— 0.83	0.00	+ 0.72	+0.13	0.02	—0.85	—0.02	+ 0.70	+0.11
16.119	1.24	—0.02	1.01	+0.09	0.09	1.33	—0.11	0.91	0.00
23.663	2.25	+0.58	2.14	—0.24	0.21	2.46	+0.37	1.93	—0.45
31.207	3.52	—0.38	2.87	+0.82	0.37	3.89	—0.75	2.49	+0.45
38.751	3.41	+0.67	3.07	—0.38	0.58	3.99	+0.08	2.49	—0.96
46.295	6.16	+0.54	5.58	+0.54	0.84	7 00	—0.30	4.74	—0.30
53.839	5.88	—0.57	4.66	+1.01	1.14	7.02	—1.71	3.52	—0.13
61.383	7.11	+1.91	6.74	—0.88	1.49	8.60	+0.42	5.25	—2.38
68.927	10.28	—0.55	8.69	+2.09	1.89	12.17	—2.44	6.80	+0.20
76.471	8.28	+0.63	6.98	—0.12	2.33	10.61	1.70	4.65	—2.45
84.015	12.83	+2.23	11.98	+0.04	2.82	15.65	0.59	9.16	2.78
91.559	13.13	—1.63	10.65	+2.98	3.35	16.48	4.98	7.30	0.37
1899.103	12.49	+3.14	11.57	—1.77	3.94	16.43	0.80	7.63	5.71
1906.647	—19.27	+0.45	+16.97	+2.79	—4.56	—23.83	—4.11	+12.40	—1.77

Cleveland, 1890 *August* 30.

COMETS 1889 I AND II, AND SOME SUGGESTIONS AS TO THE POSSIBILITY OF SEEING THE SHORT-PERIOD COMETS AT APHELION.

By E. E. BARNARD.

Two comets are now under observation at this Observatory which call for some remark concerning their singularly long duration of visibility. These are Comets 1889 I and II, both of which were discovered here, the first on September 2, 1888, and the other on March 31, 1889.

The great comet of 1811 has remained until now as having the longest known duration of visibility. It was observed for a period of 16 months and 20 days. Both of the comets mentioned above have exceeded this, and promise to remain within sight for some time to come. Both of them were observed again, Sept. 7, with the 36-inch telescope.

Comet 1889 I.

With the aid of Dr. Berberich's ephemeris, this object has been observed a number of times this year with the 12-inch equatorial. It was last observed with it for position on August 7 and 14, though it was seen on August 17 and 18, after which time it passed beyond the reach of that instrument. It had thus been under observation with the 12-inch for two years, lacking 15 days. On August 17 I observed it with the 36-inch and measured the following position:

α app't = $16^h\ 51^m\ 28^s.86$, δ app't = $-8°\ 4'\ 40''.2$.
At Mt. Hamilton M.T., 1890 August $17^d\ 8^h\ 59^m\ 3^s$.

In the great telescope the comet was round, and very gradually a little brighter in the middle, with no trace of a nucleus. It was quite conspicuous, and I estimated that it could have been easily observed if it had been only one-tenth as bright. It was of about the 13.5 or 14 magnitude. While under observation it passed centrally over a 15-magnitude star, which shone through it like a nucleus. From its present appearance, it would appear that the comet may still be visible in the great telescope a year hence.

At the observation of August 17 the comet's distance from the earth was 6.00 times the earth's mean distance from the sun, and 6.25 times that unit from the sun itself. No other comet has ever been seen at such a vast distance.

According to Dr. Berberich, the late observations fully confirm the hyperbolic character of the orbit.

Comet 1889 II.

Through the kindness of Dr. Berberich, in sending me an ephemeris in manuscript, I have been enabled to find the comet with the great telescope. It was carefully searched for several times this year with the 12-inch, but it was always too faint for that instrument. On August 23 it was looked for with the 36-inch refractor, and after some search was found quite close to the ephemeris place. The following filar-micrometer position was obtained:

α app't = $22^h\ 57^m\ 9^s.77$, δ app't = $-16°\ 15'\ 1''.9$.
At Mt. Hamilton M.T., 1890 August $23^d\ 12^h\ 57^m\ 31^s$.

It was very small and faint, and sensibly round, with no nucleus. It was estimated to be of the 14.5 or 15 magnitude. The motion towards the southwest, during the observation, was very sensible both to the eye and in the measures. Another observation was obtained of it on August 24. This comet had not been seen since November 1889.

These observations, it will be seen, also carry this comet beyond the duration of visibility of any previously known. It will be possible to carry it, at least, two months longer. At the above observations the comet's distance from the earth was 4.07, and 5.06 from the sun, which is also a greater distance than any other comet was ever visible.

Comments.

These observations, besides showing the wonderful power of the great telescope, are highly suggestive, as will be seen from the following table of the aphelion distances of the short-period comets which have been recognized at more than one return (excepting Tuttle's).

Aphelion Distances of the Short-Period Comets.

Encke's,	4.10
Temple's II,	4.66
Temple's I,	4.82
Swift's (1880),	5.14
Winnecke's,	5.50
Brorsen's,	5.66
D'Arrest's,	5.72
Faye's,	5.92
Biela's,	6.19

By examining this table, it is at once seen that comet 1889 I is now being observed at a greater distance than it is possible for any one of the above periodic comets ever to attain. Comet 1889 I was never a large or a specially bright object, and was always much below naked-eye visibility. Winnecke's comet at its return in 1886 was as bright as it, and so also was Encke's at some of its returns. The others I am not familiar with. Of course comet 1889 I has always been very distant from us. It would seem highly probable, therefore, that some of the short-period comets ought to be seen at aphelion, and hence throughout their entire orbits.

I would gladly make a search for Winnecke's or Encke's comet if an accurate ephemeris can be furnished. It is necessary that the place be pretty closely known.

It would be well to make a remark here on the observation of comets when near the time of their disappearance.

Observers as a general rule neglect comets as soon as they become faint or difficult — the very time when positions are extremely valuable. While the comet is bright, everybody observes it, but as soon as it becomes a little difficult, it is at once dropped by the majority of observers. Here, it has been the rule to take up a comet as soon as it becomes faint and difficult, when it is likely to be neglected elsewhere, and to observe it as long as it can be seen.

In receding from the sun, a comet becomes very small — all the nebulosity, except the central brightness, disappearing absolutely. What remains in view usually does not exceed 4″ or 5″ in diameter. It may be difficult to see, but it can be bisected with great exactness, indeed with as much or with more accuracy than the average bright comet devoid of a nucleus.

The accurate measurement of these faint comets is very delicate work, and requires the most perfect illumination of the wires. Ring or bar-micrometer observations would give comparatively very indifferent results. Our micrometer threads are illuminated by the very ingenious device invented by Mr. BURNHAM, and which is applied to all Clark micrometers. With this method the illumination of the wires can be varied, while the observation is going on, from the maximum brightness to total extinction. This is more necessary, perhaps, in the observation of a faint comet than in any other kind of micrometrical work. I find this method perfect for such work, and it leaves nothing to be desired. The bisections of a comet which may be visible only by averted vision, or by glimpses, can be made with perfect accuracy.

Mt. Hamilton, 1890 *September*.

ELEMENTS AND EPHEMERIS OF COMET *c* 1890 (*DENNING*),

BY LEWIS BOSS.

The elements of Comet *c* 1890, herewith transmitted, were computed from a normal place of July 27.0, the composition of which appears in a table below, — the mean between a Strassburg observation of Aug. 14.4 combined with an Albany observation of Aug. 15.6, — and the mean of two Albany observations of Sept. 4.6.

$$T = 1890\ \text{Sept.}\ 24.4974\ \text{Greenw. M.T.}$$

$$\left.\begin{array}{rl} \omega = & 163^\circ\ 1'\ 32''.6 \\ \text{☊} = & 100\ \ 7\ \ 33\ .2 \\ i = & 98\ 56\ 15\ .9 \end{array}\right\} 1890.0$$

$$\log q = 0.100382$$

The outstanding residuals in the sense, C—O, for the observations employed in the calculation of elements are as follows:

	G.M.T.	$\Delta\alpha \cos\delta$	$\Delta\delta$
	d h	s	″
Nice	July 24 11	—0.1	—3
Nice	25 9	—0.2	+8
Vienna	27 12	—0.2	—3
Strassburg	27 12	—0.4	—5
Vienna	28 10	+0.1	—2
Vienna	29 10	0.0	—5
Strassburg	Aug. 14 10	+0.1	0
Albany	15 15	—0.2	0
Albany	Sept. 4 14	+0.2	—1
Albany	4 15	—0.3	+2

The equations for 1890.0 of the comet's heliocentric equatorial coordinates are:

$$\begin{aligned} x &= r[9.367404]\ \sin(v + 114^\circ\ \ 2'\ 46''.9) \\ y &= r[9.989110]\ \sin(v + 275\ \ 12\ \ \ 7\ .8) \\ z &= r[9.998828]\ \sin(v + 186\ \ \ 9\ \ 30\ .9) \end{aligned}$$

Taking July 27.0 for the initial date, the theoretical brightness, by the customary formula, is unity for October 12, being 1.8 for Sept. 15. On Oct. 29 this quantity becomes two-thirds; on Nov. 16, one-half; and, on the last date of the subjoined ephemeris, four-tenths. Considering all the circumstances, it is very doubtful whether observers in either hemisphere will be able to see this extremely faint comet in November.

EPHEMERIS FOR GREENWICH MIDNIGHT.

1890 G.M.T.	App. α	App. δ	log r	log Δ
	h m s	° ′ ″		
Sept. 15	15 50 21.9	+ 4 36 47	0.10296	0.12505
16	15 51 16.6	3 21 59		
17	15 52 11.4	2 7 57	0.10195	0.13336
18	15 53 6.4	+ 0 55 20		
19	15 54 1.6	— 0 15 13	0.10118	0.11198
20	15 54 56.9	1 21 41		
21	15 55 52.4	2 32 46	0.10067	0.15082
22	15 56 48.0	3 39 28		
23	15 57 43.9	4 44 48	0.10011	0.15983
24	15 58 39.9	5 48 47		
25	15 59 36.1	6 51 27	0.10041	0.16895
26	16 0 32.5	7 52 50		
27	16 1 29.2	8 52 55	0.10067	0.17811
28	16 2 26.0	9 51 46		
29	16 3 23.1	10 49 23	0.10118	0.18729
30	16 4 20.4	11 45 49		
Oct. 1	16 5 18.0	12 41 5	0.10195	0.19642
2	16 6 15.8	13 35 13		
3	16 7 11.0	14 28 15	0.10297	0.20549
4	16 8 12.4	15 20 11		
5	16 9 11.1	16 11 5	0.10423	0.21445
6	16 10 10.2	17 0 58		
7	16 11 9.6	17 49 51	0.10573	0.22328
8	16 12 9.4	18 37 47		
9	16 13 9.5	19 24 47	0.10747	0.23195
10	16 14 10.0	20 10 52		
11	16 15 10.9	20 56 5	0.10944	0.24045
12	16 16 12.2	21 40 27		
13	16 17 14.0	22 23 59	0.11163	0.24877
14	16 18 16.1	23 6 43		
15	16 19 18.8	23 48 42	0.11401	0.25689
16	16 20 21.8	24 29 55		
17	16 21 25.4	25 10 25	0.11664	0.26479
21	16 25 41.3	27 45 38	0.12244	0.27994
25	16 30 11.6	30 11 5	0.12894	0.29119
29	16 34 48.0	32 27 59	0.13607	0.30752
Nov. 2	16 39 34.8	34 37 29	0.14375	0.31994
6	16 44 32.7	36 40 35	0.15191	0.33146
10	16 49 43.2	38 38 9	0.16046	0.34211
14	16 55 6.9	40 30 58	0.16934	0.35191
18	17 0 44.8	42 19 42	0.17848	0.36090
22	17 6 38.0	—44 4 57	0.18783	0.36910

OBSERVATIONS OF COMETS,

MADE WITH THE 15-INCH EQUATORIAL OF THE HARVARD COLLEGE OBSERVATORY

By O. C. WENDELL, Assistant.

[Communicated by Prof. Edward C. Pickering, Director.]

Cambridge M.T.	✱	No. Comp.	☄ — ✱ Δα	☄ — ✱ Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
Comet 1889 I.								
1890 June 10ᵈ 11ʰ 36ᵐ 18ˢ	1	11	+0ᵐ 3ˢ.21	— 6′ 59″.3	17ʰ 50ᵐ 30ˢ.15	— 6° 51′ 23″.4	n9.027	0.821
Comet 1889 V.								
1889 Oct. 2 9 34 48	1	7	—0 19.99	— 1 16.5	23 46 42.17	— 1 58 42.1	n9.196	0.810
15 8 5 39	2	5	—1 44.10	+ 5 43.5	23 44 22.69	— 4 9 20.4	n9.330	0.803
16 8 37 36	3	6	+0 39.83	— 3 0.9	23 41 8.18	— 4 4 26.5	n9.181	0.801
17 7 41 51	4	3	+0 27.27	+ 1 40.7	23 40 55.61	— 3 59 44.9	n9.382	0.802
18 7 45 34	5	5	+0 16.38	+ 6 45.6	23 40 41.72	— 3 54 40.0	n9.382	0.802
23 9 1 0	6	5	—2 0.88	— 4 30.0	23 40 15.56	— 3 27 0.5	n8.834	0.801
Nov. 5 8 11 4	7	1	+0 57.55	+ 7 27.6	23 42 40.88	— 1 59 48.7	n8.713	0.790
5 8 54 12	8	3	+0 55.92	+ 7 10.5	23 42 39.25	— 2 0 5.8	8.394	0.781
11 9 7 26	9	5	—0 49.91	— 7 16.9	23 47 13.67	— 0 47 57.3	9.274	0.780
15 8 21 9	10	5	—1 17.00	— 9 37.1	23 47 51.18	— 0 39 47.5	8.446	0.779
16 8 25 49	11	5	—0 36.58	— 1 3.8	23 48 31.59	— 0 31 14.2	8.627	0.778
22 10 23 31	12	5	—1 11.98	— 5 16.6	23 53 9.52	+ 0 23 14.5	9.449	0.772
25 10 10 14	13	5	—2 11.03	— 7 6.1	23 55 16.06	+ 0 51 13.9	9.437	0.768
25 10 10 14	14	5	—3 21.66	— 1 13.1	23 55 16.05	+ 0 51 12.6	9.437	0.768
26 10 39 1	15	5	—1 17.92	+ 2 39.1	23 56 42.17	+ 1 0 59.1	9.503	0.768
26 10 39 1	16	3	—2 25.31	+ 5 29.5	23 56 42.10	+ 1 0 55.2	9.503	0.768
29 8 16 2	17	6	+2 22.23	— 2 7.5	23 59 30.03	+ 1 29 6.5	8.996	0.762
Dec. 7 8 40 29	18	4	—0 42.82	— 6 7.1	0 8 6.95	+ 2 15 21.6	9.267	0.750
13 9 35 24	19	5	+4 0.73	—10 57.6	0 15 20.28	+ 3 52 51.5	9.175	0.718
16 8 58 13	20	5	—2 37.66	— 1 51.5	0 19 8.01	+ 4 21 15.5	9.407	0.742
19 10 13 53	21	5	+1 31.82	— 1 5.0	0 23 8.31	+ 4 57 39.1	9.563	0.750
21 9 24 21	22	5	—4 16.71	— 7 59.2	0 25 18.52	+ 5 19 2.9	9.497	0.739
23 9 3 20	23	4	—0 13.38	+ 7 1.1	0 28 33.18	+ 5 40 58.3	9.163	0.731
26 9 27 32	24	5	+1 25.82	— 5 12.6	0 32 17.70	+ 6 18 47.2	9.523	0.736
27 9 24 28	25	5	+2 22.26	+ 1 26.0	0 33 11.14	+ 6 25 25.8	9.523	0.735
1890 Jan. 14 8 9 6	26	5	—3 51.90	+ 1 51.8	1 1 19.93	+ 9 47 9.7	9.461	0.701
16 8 11 29	27	6	+1 36.28	— 4 29.2	1 5 1.81	+10 9 56.1	9.481	0.699
17 8 26 55	28	5	—4 11.10	+ 7 25.8	1 6 15.11	+10 21 13.4	9.515	0.704
18 8 41 1	29	6	+0 2.37	— 5 50.2	1 8 25.07	+10 32 37.9	9.512	0.707
20 9 15 47	30	6	+4 28.34	+ 2 27.3	1 11 18.93	+10 55 33.4	9.619	0.732
21 7 55 4	31	5	—1 2.48	— 6 7.3	1 13 22.06	+11 6 3.1	9.170	0.690
22 8 5 13	32	4	—0 21.11	— 3 36.8	1 15 3.12	+11 17 20.8	9.198	0.690
24 8 28 3	33	8	—0 37.94	— 2 29.4	1 18 27.93	+11 39 49.1	9.514	0.698
Feb. 11 8 13 2	34	10	+0 41.15	+ 8 47.1	1 49 56.63	+14 56 27.6	9.582	0.685
12 8 43 41	35	7	—0 4:28	+ 7 16.4	1 51 16.96	+15 7 13.1	9.615	0.702
15 8 37 28	36	7	+4 35.63	— 4 32.8	1 57 12.91	+15 38 32.6	9.615	0.700
20 8 38 10	37	5	+1 32.49	+ 1 46.6	2 6 22.21	+16 30 6.9	9.628	0.701
21 9 15 37	38	6	—0 1.75	+ 6 34.5	2 8 15.83	+16 40 20.5	9.652	0.726
Mar. 17 8 47 34	39	5	—0 50.09	— 9 16.7	2 53 29.15	+20 26 20.0	9.665	0.727
18 8 50 17	40	6	+1 6.71	— 1 8.0	2 55 25.96	+20 31 58.7	9.667	0.730
Companion to Comet 1889 V.								
1889 Oct. 18 8 9 59	1	1	+0 34.75	+ 9 29.1	23 41 3.09	— 3 51 56.5	n9.382	0.802
18 8 24 34	2	7	+0 34.88	+ 9 30.3	23 41 3.22	— 3 51 55.3	n9.382	0.802
18 11 49 55	3	5	+0 32.55	+10 17.3	23 41 0.89	— 3 51 8.5	9.221	0.801
23 9 27 58	4	5	—1 43.16	— 4 17.2	23 40 33.28	— 3 21 17.7	n8.831	0.801
Nov. 11 9 51 32	5	6	—0 33.62	— 1 15.6	23 47 29.99	— 0 45 26.0	8.416	0.779
15 8 4 10	6	5	—1 2.06	— 7 21.2	23 48 6.12	— 0 37 31.6	8.627	0.778
16 8 4 29	7	4	—0 22.12	+ 1 8.0	23 48 46.05	— 0 29 2.4	9.149	0.772

Cambridge M.T	*	No. Comp.	☄ − * Δα	☄ − * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
Comet *a* 1890 (Brooks, *March 19*).								
1890 d h m s			m s	′ ″	h m s	° ′ ″		
Mar. 21 16 57 35	1	6	+0 42.25	− 5 4.9	21 9 31.15	+ 6 25 30.4	n9.594	0.746
24 16 57 5	2	6	+1 27.08	+ 4 10.8	21 10 10.41	+ 7 40 13.0	n9.582	0.737
30 16 8 39	3	5	+0 40.34	− 0 15.2	21 10 57.81	+10 19 49.4	n9.612	0.722
May 21 11 1 33	4	7	+0 26.60	+ 1 52.7	20 16 13.85	+48 31 1.4	n9.811	0.476
23 11 26 58	5	5	−2 3.27	+11 55.3	20 8 9.48	+50 29 30.1	n9.805	0.281
24 11 14 21	6	5	−1 19.74	+ 2 54.7	20 3 49.14	+51 27 17.0	n9.819	0.281
June 9 12 5 48	7	5	−0 11.22	+ 7 1.8	18 6 49.20	+63 59 58.8	n9.304	n0.501
25 11 20 40	8	4	−2 15.57	−13 15.4	15 20 28.62	+61 2 28.9	9.712	n0.358
30 12 11 31	9	1	+3 10.09	+ 5 49.5	14 12 59.46	+61 49 54.1	9.908	0.000
July 9 11 56 21	10	6	+2 19.53	+ 0 42.5	13 57 53.00	+57 2 9.7	9.896	0.315
11 11 8 39	11	5	+1 17.64	+ 0 28.7	13 50 50.86	+55 57 9.5	9.865	0.157
Comet *b* 1890 (Coggia, *July 18*).								
July 21 10 29 23	1	3	+2 4.89	− 9 26.0	9 13 3.36	+42 22 7.7	9.644	0.176
22 9 23 54	2	4	−0 47.98	− 3 27.8	9 19 54.02	+41 37 13.7	9.487	9.871
23 9 16 18	3	5	−4 43.48	+ 4 46.6	9 26 45.66	+40 18 53.3	9.446	9.877
Comet *c* 1890 (Denning, *July 23*).								
July 27 13 21 25	1	5	−1 41.49	−10 38.4	15 13 41.73	+74 16 8.5	0.203	0.391

Mean Places for 1890.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	17 50 25.27	+1.67	− 7 1 20.9	−1.79	Lam. (−3 to −9 Suppl.) 2508
	1889.0		1889.0		
1	23 16 59.69	+2.47	− 4 54 41.4	+15.8	W_1 23^h 915
2	23 43 4.36	+2.43	− 4 15 19.3	+15.4	Sj. 9844
3	23 40 25.92	+2.43	− 4 1 41.0	+15.4	Sj. 9824
4	23 40 25.92	+2.42	− 4 1 41.0	+15.4	Sj. 9824
5	23 40 25.92	+2.42	− 4 1 41.0	+15.4	Sj. 9824
6	23 42 14.05	+2.39	− 3 22 45.8	+15.3	W_1 23^h 823
7	23 41 41.04	+2.29	− 2 7 31.2	+14.9	B.B. VI (Suppl. −2 to −14)
8	23 41 41.04	+2.29	− 2 7 31.2	+14.9	B.B. VI (−2° to −14° 40′) Suppl.
9	23 48 1.35	+2.26	− 0 40 55.4	+15.0	7 comps. with Ll. 46859–60
10	23 49 5.92	+2.26	− 0 30 25.4	+15.0	Ll. 46859–60
11	23 49 5.92	+2.25	− 0 30 25.4	+15.0	Ll. 46859–60
12	23 54 19.28	+2.22	+ 0 28 16.3	+14.8	W_1 23^h 1075
13	23 57 57.89	+2.20	+ 0 58 5.3	+14.7	B.B. VI, +0° 5082
14	23 59 5.51	+2.20	+ 0 55 11.0	+14.7	W_1 23^h 1179
15	23 57 57.89	+2.20	+ 0 58 5.3	+14.7	B.B. VI, +0° 5082
16	23 59 5.51	+2.20	+ 0 55 11.0	+14.7	W_1 23^h 1179
17	23 57 5.63	+2.17	+ 1 30 59.3	+14.7	W_1 23^h 1143
18	0 8 17.65	+2.12	+ 2 51 14.1	+14.6	B.B. VI, +2° 18
19	0 14 17.43	+2.12	+ 4 3 37.7	+14.4	W_1 0^h 207
20	0 21 43.56	+2.11	+ 4 26 25.6	+14.4	B.B. VI, +4° 57
21	0 21 31.38	+2.11	+ 5 1 30.1	+14.3	Albany Zones, no. 80
22	0 27 3.15	+2.11	+ 5 26 47.8	+14.3	W_1 0^h 422
23	0 29 14.45	+2.11	+ 5 33 42.6	+14.3	B.B. VI, +5° 74
24	0 31 19.78	+2.10	+ 6 23 45.6	+14.2	B.B. VI, +6° 78
25	0 31 19.78	+2.10	+ 6 23 45.6	+14.2	B.B. VI, +6° 78
	1890.0		1890.0		
26	1 5 42.89	−1.06	+ 9 42 23.6	− 5.7	W_1 1^h 39
27	1 3 29.60	−1.07	+10 14 31.0	− 5.7	W_1 1^h 2
28	1 8 0.62	−1.08	+10 13 53.2	− 5.6	W_1 1^h 76
29	1 8 23.79	−1.09	+10 38 33.7	− 5.6	B. B. VI, +10° 150
30	1 10 21.72	−1.10	+10 53 11.7	− 5.6	W_1 1^h 119

*	α	Red. to app. place	δ	Red. to app. place	Authority
31	1 14 25.61	−1.07	+11 12 15.8	− 5.4	7 comps. with W_1 1^h 208
32	1 15 28.30	−1.07	+11 21 3.0	− 5.4	W_1 1^h 208
33	1 19 6.94	−1.10	+11 42 23.9	− 5.4	7 comps. with W_1 1^h 257
34	1 49 16.68	−1.20	+14 48 15.9	− 5.4	Ll. 3527
35	1 51 52.44	−1.20	+15 0 2.3	− 5.3	7 comps. with Ll. 3527
36	1 55 38.48	−1.20	+15 43 10.5	− 5.1	B.B. VI, +15° 291
37	2 4 51.25	−1.23	+16 28 25.2	− 4.9	5 comps. with W_2 2^h 124
38	2 8 18.82	−1.24	+16 33 50.8	− 4.8	7 comps. with W_2 2^h 124
39	2 54 20.60	−1.36	+20 36 10.7	− 4.0	W_2 2^h 1260
40	2 54 20.60	−1.38	+20 36 10.7	− 4.0	W_2 2^h 1260
	1889.0		1889.0		
1	23 40 25.92	+2.42	− 4 1 41.0	+15.4	Sj. 9824
2	23 40 25.92	+2.42	− 4 1 41.0	+15.4	Sj. 9824
3	23 40 25.92	+2.42	− 4 1 41.0	+15.4	Sj. 9824
4	23 42 14.05	+2.39	− 3 22 45.8	+15.3	W_1 23^h 823
5	23 48 1.35	+2.26	− 0 40 55.4	+15.0	7 comps. with Ll. 46859–60
6	23 49 5.92	+2.26	− 0 30 25.4	+15.0	Ll. 46859–60
7	23 49 5.92	+2.25	− 0 30 25.4	+15.0	Ll. 46859–60
	1890.0		1890.0		
1	21 8 53.16	−1.26	+ 6 30 47.3	−12.0	W_1 21^h 132
2	21 8 44.57	−1.21	+ 7 39 14.4	−12.2	W_1 21^h 125
3	21 10 18.52	−1.05	+10 20 17.3	−12.7	W_1 21^h 171
4	20 15 46.24	+1.01	+48 29 21.5	−15.8	Oe. A. 20377
5	20 10 11.57	+1.18	+50 17 50.3	−15.5	Oe. A. 20210
6	20 5 7.62	+1.26	+51 24 10.6	−15.3	Oe. A. 20093
7	18 6 57.37	+3.05	+63 53 1.9	− 4.9	Lalande 33621
8	15 22 41.72	+2.47	+64 15 33.8	+10.5	Oe. A. 15387–88
9	14 39 17.58	+1.79	+61 43 51.6	+13.0	Oe. A. 14810
10	13 55 32.45	+1.02	+57 1 13.1	+14.1	B.B. VI, +57° 1473
11	13 49 2.33	+0.89	+55 56 26.7	+14.1	10 comps. with Oe. A. 14080
	1890.0		1890.0		
1	9 10 59.07	−0.73	+42 31 29.9	+ 5.0	Ll. 18261
2	9 20 42.85	−0.69	+41 40 34.8	+ 5.2	W_2 9^h 389
3	9 31 29.86	−0.66	+40 41 0.1	+ 5.1	W_2 9^h 613–14
	1890.0		1890.0		
1	15 18 21.43	+1.47	+74 26 31.2	+15.4	Oe. A. 15 15348

REMARKS.

COMET 1889 V.

1889 Oct. 2. Moonlight rather strong. Nucleus fairly well defined.

Oct. 15. Nucleus not very sharp. Diameter of total nebulosity 1'.5. Faint wisp visible on following side.

Oct. 16. Nucleus not very sharply defined. Seems to have a somewhat granulated structure. Faint wisp on north following side. Diameter of total nebulosity 1'.5.

Oct. 18. Nucleus not very sharply defined. Diameter of total nebulosity same as last night.

Oct. 23. Comet rather faint. Sky slightly hazy.

Nov. 5. Comet very faint in moonlight.

Nov. 22. Companion comet seen but cannot be taken in transit.

Nov. 25. Comet 1' in diameter. Tail 2'.5 in length.

Nov. 26. Sky hazy.

Nov. 29. Comet faint in moonlight. Companion not seen.

Dec. 7. Comet faint.

Dec. 13. Nucleus rather sharply defined. Diameter of total nebulosity 1'. Faint tail 2' long. Companion comet not seen.

Dec. 16. Nucleus not very well defined. Diameter of principal nebulosity 1'.2. Diameter of total nebulosity 2'.5.

Dec. 19. Sky hazy.

Dec. 26. Faint tail visible.

Dec. 27. Observation $\frac{2}{3}$ weight.

1890 Jan. 14. Comet faint. Nucleus somewhat stellar. Companion comet suspected a little south following principal comet but too faint for observation.

Jan. 16. Observation $\frac{2}{3}$ weight. A second nucleus, a little north following, suspected.

Jan. 17. Comet faint. Nucleus rather stellar. Second nucleus of last night confirmed.

Jan. 18. Observation $\frac{2}{3}$ weight. Some cloud and haze.

Jan. 20. Observation $\frac{2}{3}$ weight.

Jan. 21. Nucleus rather well defined. Diameter of total nebulosity 1'. Faint tail 2' long.

Jan. 22. Comet well defined.

Jan. 24. Comet rather faint, moon near.

Feb. 11. Nucleus fairly well defined.

Feb. 12. Comet rather faint.

Feb. 15. Observations $\frac{2}{3}$ weight.

Feb. 20. Seeing rather poor.

Feb. 21. Comet faint.

March 18. Comet very faint. Nucleus slightly stellar.

COMPANION TO COMET 1889 V.

1889 Nov. 14. Comet exceedingly faint. Observation $\frac{2}{3}$ weight. No central condensation apparent.

Nov. 15. Comet very faint. Seeing rather poor. No central condensation.

Nov. 16. Comet very faint.

COMET *a* 1890 (BROOKS *March 19*).

1890 July 11. A comparison of this observation with CAMPBELL'S Ephemeris as given in the *Astronomical Journal*, Vol. X, p. [illegible] and corrected as indicated on p. 45, shows a difference of some 11 seconds, which can not at present be accounted for.

ON PHOTOGRAPHING STARS IN THE DAY-TIME.

BY EDWARD S. HOLDEN.

[Second Note.]

In the *Astronomical Journal*, vol. IX, page 73, I printed a simple theory of photographing stars projected against a bright background. Since that time the question has been examined experimentally by Mr. W. W. CAMPBELL and myself, using the great telescope (focus 570 inches), and apertures of 33, 15, 8 and 4 inches. Photographs of *Venus*, *Mercury*, the *Moon* and of *Alpha Lyrae*, have been taken in broad day-light (2 to 5 P.M.) with the apertures named, with a constant exposure of $0^s.13$, and on Seed 26 plates. In general, the smallest apertures used have given the darkest images, as demanded by the theory. I inclose with this a paper print of *Alpha Lyrae*, made with 15 inches aperture. The results have a theoretical value in their bearing on the problem of registering very small contrasts — as in photography of the Corona for example. Practically it will be of value to be able to refer the *Moon* or one of the inferior planets to a bright star near it; at any time day or night.

Lick Observatory, 1890 *August* 19.

NEW ASTEROIDS.

Mr. CHARLOIS of Nice announces the discovery of two new asteroids, on the night of Sept. 9, being nos. 297 and 298 of the group. Their positions were,

1890 Sept. 9.3857 Gr. M.T.	$\alpha = 22^h\ 21^m\ 18^s.5$,	$\delta = -9^\circ\ 2'\ 28''$.	12^M	Daily motion, -48^s, and 1′ southward
1890 Sept. 9.5364 Gr. M.T.	$\alpha = 0^h\ 38^m\ 32^s.9$,	$\delta = +2^\circ\ 40'\ 4''$.	13^M	Daily motion, -56^s, and 1′ southward

NEW ASTRONOMICAL WORK.

Astronomical Papers prepared for the use of the American Ephemeris and Nautical Almanac. Vol. IV. — *A new Theory of Jupiter and Saturn, by* G. W. HILL, *Assistant American Ephemeris.* Washington, 1890.

In this volume we have the first instalment of a revision of the theories of the eight major planets, undertaken by, and under the direction of, Prof. NEWCOMB. Prof. HILL has determined complete analytical expressions for the coordinates of the two planets in question; and has given a preliminary comparison of his theory with observation. The method followed in the investigation is that of HANSEN,— expressing the coordinates, however, in terms of the mean instead of the eccentric anomalies. The paper, therefore, may be regarded as a revision and completion of HANSEN's Berlin Prize Memoir on this subject. For the development of the quantities in periodic series the shorter methods of the later memoir, entitled *Auseinandersetzung*, etc., are employed.

The fundamental arguments of the two planets are equated in such a way that they take account of all the inequalities of the reduction to the ecliptic, secular and periodic, and also of all that part of precession which involves the square and higher powers of the time. The ecliptic longitudes can thus be tabulated directly, without the necessity for arriving at them through the intermediation of the orbit-longitudes. In Chap. XXVI we have a new determination of the motion of the ecliptic, and differential equations are given for deriving the obliquity and general precession, independently of the luni-solar precession.

In Chap. XXIX the formulas of HANSEN for correcting the perturbations on account of determinate changes in the elements are simplified and rendered more easily applicable in the cases where the eccentricities are small.

So far as comparison with observation is capable of showing, this elaborate and able investigation appears eminently successful — far surpassing previous ones in this respect. It is not probable that it will soon need to be undertaken anew.

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SUPPLEMENT TO "SECULAR AND LONG-PERIOD INEQUALITIES IN THE MOON'S MOTION," BY PROF. JOHN N. STOCKWELL.
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ON PHOTOGRAPHING STARS IN THE DAY-TIME, BY PROF. EDWARD S. HOLDEN.
NEW ASTEROIDS.
NEW ASTRONOMICAL WORK.

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ASTRONOMICAL JOURNAL.

No. 226.

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THE SECULAR VARIATION OF THE MOTION OF THE MOON'S PERIGEE.

By G. W. Hill.

In nos. 220 and 221 of this Journal appears an article by Mr. **Stockwell**, in which, in opposition to all previous investigators, an acceleration is found for the motion of this element of the lunar orbit. The introductory history of this matter given by the author is incomplete, as he passes over without notice the most recent, and perhaps the only correct, determination of the coefficient, viz.: that by **Delaunay** (*Comptes Rendus*, Tome LXXIV. pp. 152, 153). **Delaunay** finds that, assuming $-1270'' i^2$ as the value of $n\int(e'^2-e_0'^2)dt$, the coefficients of i^2 in the motions of the perigee and node are severally $-39''.986$ and $+6''.778$.

Before astronomers accept the new values advanced by Mr. **Stockwell**, in order to judge intelligently about the matter, they doubtless would like to know how it happens that the author differs so greatly from his predecessors. No information in the article itself is given on this point; it is strange that the author should deem this a matter of no importance. The explanation is not far to seek: the quantities e and ω, which appear in the author's equation (1), are treated as though they suffered no periodic perturbations. Yet the equation is not true unless these two symbols denote severally the eccentricity and longitude of the perigee in the instantaneous orbit which the moon is, at the moment, describing. All the previous investigators, while they do not employ equation (1), have employed methods in which this principle is tacitly admitted. It should be pointed out that equation (1) is not in the shape astronomers generally give it. It appears that the lunar elements have been partially eliminated from it by the introduction of the differential coefficients

$$\frac{dv}{dt} \text{ and } \frac{dr}{dt}$$

But the method followed by the author requires that the elimination should be complete; no instantaneous element of the moon should appear in the equation. Very simple equations exist suitable for this purpose; such, for instance, as

$$\mu e\cos(v-\omega) = r^3\frac{dv^2}{dt^2} - \mu$$

$$\mu e\sin(v-\omega) = r^2\frac{dr}{dt}\frac{dv}{dt}$$

The equation would then take the form

$$\frac{d\omega}{dt} = \frac{r^2\frac{dr}{dt}\left[r^3\frac{dv^2}{dt^2}-\mu\right]\cdot\left(\frac{dR}{dr}\right) - \frac{dr}{dt}\left[r^3\frac{dv^2}{dt^2}+\mu\right]\cdot\left(\frac{dR}{dv}\right)}{\left[r^3\frac{dv^2}{dt^2}-\mu\right]^2 + r^4\frac{dr^2}{dt^2}\frac{dv^2}{dt^2}}$$

in which the right member is expressed purely as a function of the four quantities

$$r,\ v,\ \frac{dr}{dt} \text{ and } \frac{dv}{dt}$$

It may be thought the equation in this shape is too cumbrous for use; and so it is. For this reason it has not been employed by astronomers. The method followed by **Delaunay**, for instance, involves far less labor. This method furnishes the equations

$$\frac{dg}{dt} = -\frac{dR}{dG}, \qquad \frac{dh}{dt} = -\frac{dR}{dH}$$

But it is more convenient to express R in terms of a, e and γ, than in terms of L, G and H; hence we write

$$\frac{d\omega}{dt} = -\left(\frac{da}{dG}+\frac{da}{dH}\right)\frac{dR}{da} - \left(\frac{de}{dG}+\frac{de}{dH}\right)\frac{dR}{de} - \left(\frac{d\gamma}{dG}+\frac{d\gamma}{dH}\right)\frac{dR}{d\gamma}$$

This equation holds true through all the transformations **Delaunay** makes for the purpose of removing from R the various periodic terms it contains by reason of the action of the sun. In these transformations, however, e' the solar eccentricity is treated as a constant. It is, however, variable, and it is permitted to conceive it as developed in ascending powers of t. Hence, wherever, in the old development of R, we wrote e', we ought now to write $e'_0 + ft$, e_0 and f being regarded as constants. The new portion of R is then

$$\frac{dR}{de'}.ft$$

for, limiting the determination of the secular variation to the term proportional to t^2, it is not necessary to go beyond the first power of t. And, in this new portion of R, we ought to make all the transformations of variables which have as object the removal of the periodic terms of the earlier portion of R. Again, it is plain that the e', which appears in the still-remaining non-periodic term of the earlier portion of R, should be regarded as constant; that is, e'_0 should be substituted for it. Also, the making the transformations in

$$\frac{dR}{de'}ft$$

is the same thing as substituting in it, for the three coordinates of the moon, their values as affected by solar action. This being done, and the resulting function limited to its non-periodic term, it is plain the term we are in search of will be given by the integration of the equation

$$\frac{d\omega}{dt} = -\left\{\left(\frac{da}{dG}+\frac{da}{dH}\right)\frac{d^2R}{dade'} + \left(\frac{de}{dG}+\frac{de}{dH}\right)\frac{d^2R}{dede'} + \left(\frac{d\gamma}{dG}+\frac{d\gamma}{dH}\right)\frac{d^2R}{d\gamma de'}\right\}ft$$

In this care must be taken to have a, e and γ of the same signification in all the factors. When we neglect the inclination of the lunar orbit the last term may be neglected.

The advantage of the employment of such a formula as this over the one employed by Mr. Stockwell consists in the circumstance that since the first factors are non-periodic, the second may be limited to their non-periodic terms. The expression is correct, however far we may wish to push the approximation in reference to powers of the solar disturbing force.

It would be impossible to give here a redetermination of the coefficient in dispute to the degree of approximation adopted by Delaunay, on account of its length. Nevertheless, some approximate statements may be of interest. In another place I have found (*Astronomical Papers of the American Ephemeris*, Vol. III, p. 388),

$$an\left(\frac{da}{dG}+\frac{da}{dH}\right) = -0.003395, \qquad a^2ne\left(\frac{de}{dG}+\frac{de}{dH}\right) = -1.049$$

When we neglect the inclination of the lunar orbit and the solar parallax, with Delaunay's notation, we have

$$R = \tfrac{1}{4}\,n'^2\frac{a'^3}{r'^3}r^2 + \tfrac{3}{4}\,n'^2\frac{a'^3}{r'^3}r^2\cos 2(h+r+h'-r')$$

Thence we derive

$$\frac{dR}{de'} = -3R\frac{d.\log r'}{de'} - \frac{dR}{dv}\frac{dv'}{de'}$$

Here it will be sufficiently accurate to put

$$-3\frac{d.\log r'}{de'} = -\tfrac{3}{2}e' + 3\cos l', \qquad \frac{dv'}{de'} = 2\sin l'$$

Then, if we suppose the disturbing function and its derivative contains severally the terms

$$R = a^2n^2(A_0+A_1e'\cos l'), \qquad \frac{dR}{dv} = Ba^2n^2e'\sin l'$$

where A_0, A_1 and B are functions of a and e only, we shall have

$$\frac{dR}{de'} = a^2n^2\left\{\tfrac{3}{2}(A_1-A_0) - B\right\}e'$$

From Pontécoulant's *Théorie Analytique du Système du Monde*, Tome IV, pp. 100, 106, 185, 253 and 256, we get

$$A_0 = \tfrac{1}{4}\,m^2 - \tfrac{179}{96}\,m^4 + (\tfrac{3}{8}\,m^2+\tfrac{225}{32}\,m^3+\tfrac{16751}{512}\,m^4)e^2$$
$$A_1 = \tfrac{3}{4}\,m^2 - \tfrac{163}{16}\,m^4 + (\tfrac{9}{8}\,m^2+\tfrac{975}{32}\,m^3+\tfrac{105357}{512}\,m^4)e^2$$
$$B = (\tfrac{75}{8}\,m^3+\tfrac{825}{32}\,m^4)e^2$$

Thus the function $\frac{dR}{de'}$ would contain the terms

$$\left\{\tfrac{3}{4}m^2 - \tfrac{799}{64}\,m^4 + (\tfrac{9}{8}\,m^2+\tfrac{825}{32}\,m^3+\tfrac{119709}{512}\,m^4)e^2\right\}a^2n^2e'$$

Pontécoulant's and Delaunay's e are not quite identical; but neglecting the difference, substituting this expression in our formula, and adopting $-1270''\,i^2$ as the value of $n\int(e'^2-e'^2_0)dt$, we get as the coefficient $-33''$ instead of Delaunay's $-10''$. The difference is caused, in the main, by our neglect of the terms of higher orders.

In conclusion, it should be stated that it is not true that when we have derived a formula such as

$$\omega = \omega_0 + (A+Be'^2)t$$

on the supposition that the solar eccentricity is constant, we shall have, as the proper correction to this when the eccentricity is variable, the formula

$$\delta\omega = B\int(e'^2-e'^2_0)dt$$

Delaunay has given the value of B (*Comptes Rendus*, Tome LXXIV, pp. 15–17), and a difference will be observed between the coefficients.

Washington, D.C., 1890 *September* 8.

OBSERVATIONS OF THE SATELLITES OF *MARS* IN 1890,

MADE AT THE U. S. NAVAL OBSERVATORY.

By A. HALL.

[Communicated by the Superintendent.]

Phobos.

Date	Washington M.T.	p	No. comp.	Washington M.T.	s	No. comp.	C—O Δp	C—O Δs
1890	h m	°		h m	″		°	″
May 28	12 30.7	126.86	4	12 38.2	25.96	4	—1.56	+0.46
29	11 22.7	124.24	4	11 28.2	25.55	4	+0.40	+0.85
30	10 23.1	127.94	4	10 32.1	25.55	4	—2.82	+0.95
June 4	9 10.7	306.41	4	. . . . . .	. . . . .	. .	+1.01	. . . .
7	9 43.7	128.91	4	9 50.2	27.25	4	—2.70	—0.63

Deimos.

Date	Washington M.T.	p	No. comp.	Washington M.T.	s	No. comp.	C—O Δp	C—O $\Delta\delta$
1890	h m	°		h m	″		°	″
May 15	11 45.2	306.06	4	11 53.7	62.81	4	—0.79	—1.03
27	10 36.7	126.27	5	10 44.7	65.22	4	—1.11	+0.72
29	10 14.7	310.46	4	10 20.2	62.42	4	+0.17	—2.21
29	11 37.2	314.13	4	11 43.7	52.50	4	+0.93	—2.19
June 8	10 5.7	306.88	4	10 13.2	67.86	4	—0.94	—1.29
25	9 28.7	124.50	4	9 37.7	58.13	4	—2.19	+1.35

NOTE.

The position of the planet was so low that the satellites were faint, and were observed with difficulty. The observations have been compared with MARTH's ephemeris. The residuals show that the periodic times of the satellites are nearly correct.

On several nights Prof. SCHIAPARELLI's double canals were looked for, but the image of the planet was blazing and unsteady, and the canals were not seen.

1890 Sept. 17.

POSITIONS OF 465 COMPARISON-STARS DETERMINED AT ALBANY.

BY LEWIS BOSS.

The accompanying catalogue of star-positions is mainly the result of efforts, in 1886 and 1887, to determine the positions of all comparison-stars used in the observations upon the great September comet of 1882. The last nine stars were employed in observations of *Polyhymnia* at the Litchfield Observatory, and are faint stars not included in the program of the Albany A.G. Zone. The observing list for the comet comparison-stars was furnished by Professor H. A. HOWE of Denver, whose request for observations of those stars most in need of new determinations led to the more extended undertaking, the results of which are here presented. The catalogue does not, in general, contain the positions of the standard stars, nor does it contain positions of all other stars used in comparisons with the comet. The failure in completeness originates partly in the faintness of some of the stars, which could not conveniently be observed with bright-field illumination; partly through the great crowding of stars in certain minutes of right-ascension; and very largely from omissions and unavoidable imperfections of the observing list.

It had occurred to me that the theory of the September comet of 1882 possesses uncommon interest from more than one point of view; and that this interest may become very intense and extremely inquisitive during the twenty-seventh century, when the fragments of the comet shall successively make their next appearance at perihelion, and when the positions of comparison-stars may be investigated with a degree of rigor unattainable at the present time. On the other hand, the researches of Dr. KREUTZ have shown that much more than half of these comparison-star positions had been already very well determined when the writer undertook this series of observations. If this fact had been so well realized then as now it would have led to a very decided modification of the program, and to one more in consonance with the original request of Professor HOWE. However, it is to be hoped that this work may not be considered altogether superfluous, and, that it may serve at some future time as an additional and not unimportant term of comparison, by which the systematic discordances of various partial series of observations may be determined and applied.

The general processes of observation and reduction for this series are practically the same as those which prevailed in the production of the list of 190 comparison-stars contained in the *Astronomical Journal*, no. 223. The transits were observed by the writer, and the microscopes were read by Assistant EGBERT. Two opposite microscopes were read at each observation, and usually a separate pair for the second observation of a given star; so that most of the catalogue-positions are affected with the mean error of eight circle-divisions.

The circle has been used invariably in the position, Clamp East, since the year 1878.

The observations of the present series are differential both in right-ascension and declination. For convenience the standard stars were selected from the *Berlin Jahrbuch*; but the declinations were first corrected by quantities derived from the following table:

δ	Corr'n	δ	Corr'n
°	″	°	″
0	+0.2	—20	+0.5
— 5	+0.2	—25	+0.6
—10	+0.2	—30	+0.6
—15	+0.3		

Consequently the positions of the present catalogue are supposed to be substantially conformable in declination to the system of the *American Ephemeris*; but the right-ascensions still require a correction of, perhaps, +0.015, to reduce them to that system.

In this series of observations, the writer endeavored to break up the habit, which he had previously formed, of observing transits in such a manner that the sound of the tap on the observing key should seem to be coincident with the bisection of the star on the transit thread. This practice had been followed throughout the observations for the Albany A.G. Zone. In the observations for the present series, an effort was made to restrain the impulse to tap the key until the instant when the star was actually seen to be bisected. Whether, in accordance with intention, this plan has caused the error of transit dependent on magnitude, which is exhibited in the observations for the Albany A.G. Zone, to disappear, is a problem which remains for future investigation. At any rate, the writer found it impossible to attain that degree of accuracy in the observation of transits by the adopted method, which had apparently been reached under the employment of his former method; and there may have been lapses of attention, at times, when the former method was unconsciously used.

The probable casual error of observation (including faint stars and irrespective of the factor cos δ) was determined by comparison of pairs with the following results:

δ	No. Prs.	Mean $\Delta\alpha$	Mean $\Delta\delta$	*p.e.* α	*p.e.* δ
° °		s	"	"	"
0 to —20	189	0.072	0.85	±0.018	±0.57
—20 to —31	247	0.082	1.00	±0.055	±0.67
0 to —31	436	0.077	0.93	±0.052	±0.63

The observations, especially in 5^h and 6^h of right-ascension, were at times made with very great haste, and were carried on in any state of atmosphere which permitted the stars to be seen at all. The resulting probable error of a single observation is, therefore, somewhat larger than that which might have been attained by more deliberate observation under selected conditions.

The arrangement of the catalogue, and of the notes in the last column, appears to require no special explanation. It may be remarked, however, that comparisons of the positions of this catalogue with lists of places from older catalogues reduced to the epochs 1882 and 1883 (kindly loaned by Professor HOWE) resulted in the detection, in a few instances, of proper motions which do not appear to have been hitherto reported. Among these were some which, though apparently real, were either too small, or too uncertain to justify evaluation at the present time. Those for which computations were made are embraced in the following list:

No.	R.A. 1882.0	δ 1882.0	μ	μ	
	h m s	° '	s	"	
292	9 24 27	—26 5	—0.0078	0.00	Pi., Cape, 1840, etc.
364-5	10 1 2	—18 44	+0.0090	—0.104	Lal., Bonn.
374	10 2 17	—19 10	—0.011	—0.35	Lal., Oe.A.
377	10 3 27	—14 55	—0.0068	—0.237	Lal., Bessel, Oe.A. etc.
379	10 3 37	—17 34	—0.0060	—0.146	Lal., Bonn, etc.
388	10 5 41	—18 22	+0.009	—0.11	Lal., Bonn.
403	10 15 8	—14 54	—0.0120	+0.268	Lal., Lam., Par., etc.
456	10 46 53	— 6 10	—0.0085	—0.233	Lal., Bessel.

The magnitudes given in the third column of the subjoined catalogue result from estimates made at the telescope during observation. Since more than half of these were made upon nights when the sky was unfavorable to trustworthy estimates of magnitude, they possess but little independent value, but they may serve to aid in some future investigation as to effect of apparent magnitude upon observed right-ascension.

CATALOGUE OF COMPARISON-STARS FOR THE EPOCH 1886.0.

No.		Magn.	No. Obs.	Epoch 1880+	α 1886.0	Prec.	δ 1886.0	Prec.	
					h m s	s	° ' "	"	
1	SDM. —14°1267	8.4	2	6.15	5 47 21.72	+2.7251	—14 35 6.2	+ 1.105	
2	SDM. —15 1203	9.0	2	6.16	47 46.48	2.7121	15 6 9.5	1.069	
3	SDM. —15 1212	7.9	2	6.15	49 16.36	2.6956	15 45 17.1	0.938	
4	SDM. —12 1310	8.6	2	6.61	49 42.45	2.7651	12 57 31.4	0.900	DM. $7^M.5$
5	SDM. —14 1277	8.8	1	7.16	49 57.79	2.7394	14 0 8.8	0.878	
6	SDM. —13 1303	9.2	2	6.66	50 19.54	2.7480	13 38 24.1	0.846	
7	SDM. —11 1326	9.0	2	6.60	50 31.66	2.7964	11 40 33.0	0.829	DM. $8^M.5$
8	SDM. —15 1217	8.8	2	6.66	50 37.71	2.7094	15 12 14.8	0.820	
9	SDM. —13 1305	8.2	2	6.67	50 51.43	2.7602	13 9 13.0	0.800	DM. $7^M.5$
10	SDM. —14 1280	9.2	2	7.19	50 56.18	2.7287	14 25 55.8	0.793	
11	SDM. —14 1282	10.0	1	6.16	50 56.91	2.7316	14 18 36.5	0.792	
12	SDM. —14 1281	9.6	1	6.19	50 57.17	2.7382	14 2 41.6	0.791	
13	SDM. —15 1221	8.8	2	6.67	51 1.56	2.7009	15 32 24.8	0.785	DM. $8^M.3$
14	SDM. —16 1302	8.7	3	6.84	51 7.47	2.6706	16 44 34.2	0.776	
15	SDM. —14 1287	9.3	3	6.14	51 15.64	2.7232	14 38 46.6	0.764	
16	SDM. —14 1288	9.0	2	6.66	51 19.96	2.7170	14 53 34.7	0.759	DM. $9^M.6$
17	SDM. —13 1306	8.4	2	6.66	51 29.18	2.7597	13 10 27.3	0.745	
18	SDM. —11 1333	8.8	2	6.62	51 29.32	2.7939	11 46 41.6	0.745	
19	SDM. —13 1310	9.0	2	6.67	51 49.60	2.7420	13 53 13.7	0.715	
20	SDM. —14 1290	9.6	2	6.67	51 55.72	2.7161	14 55 53.1	0.706	
21	SDM. —15 1226	[9.0]	2	6.16	5 52 31.37	+2.7039	—15 25 11.7	+ 0.654	DM. $7^M.2$

No.		Magn.	No. Obs.	Epoch 1880+	α 1886.0	Prec.	δ 1886.0	Prec.	
					h m s	s	° ′ ″	″	
22	SDM. —12° 1321	9.0	2	6.66	5 52 32.85	+2.7738	—12 35 53.8	+ 0.652	
23	SDM. —16 1309	9.4	2	6.66	52 32.55	2.6861	16 7 23.8	0.652	
24	SDM. —14 1292	8.2	2	6.68	52 35.16	2.7338	14 13 23.2	0.649	
25	SDM. —12 1323	9.0	1	6.15	52 45.45	2.7703	12 41 31.8	0.634	
26	SDM. —15 1229	8.9	2	6.64	52 47.17	2.6960	15 14 9.3	0.631	
27	SDM. —12 1325	8.4	2	6.18	52 56.67	2.7838	12 11 6.4	0.617	
28		9.5	1	6.19	53 0.73	2.6763	16 30 52.0	0.611	
29	SDM. —10 1332	7.7	2	6.70	53 9.89	2.8163	10 51 3.5	0.598	
30	SDM. — 9 1285		3	6.82	53 39.63	2.8472	9 31 0.8	0.555	U.A. $5^{\mathrm{M}}.7$
31	SDM. —14 1300	8.2	2	6.15	54 32.16	2.7214	14 42 59.6	0.478	
32	SDM. —15 1238	8.2	2	6.16	54 38.75	2.6910	15 48 41.7	0.468	
33	SDM. —10 1339	9.3	2	6.11	54 49.61	2.8259	10 27 14.4	0.453	
34	SDM. —15 1239	8.6	2	6.60	54 51.00	2.7125	15 4 22.6	0.416	
35	SDM. —10 1341	9.0	2	6.64	55 18.38	2.8360	10 1 58.8	0.411	
36	SDM. —10 1343	8.4	2	6.17	55 21.67	2.8323	10 11 12.5	0.406	DM. $8^{\mathrm{M}}.8$
37	SDM. —15 1242	8.4	2	6.17	55 38.51	2.7111	15 0 28.0	0.381	
38	SDM. —10 1344	8.2	2	6.68	55 39.09	2.8352	10 4 4.0	0.380	
39	SDM. —10 1347	9.0	2	6.61	55 59.91	2.8335	10 8 15.6	0.350	
40		9.2	2	6.65	56 25.10	2.6794	16 23 57.5	0.313	
41	SDM. —16 1333	7.9	3	6.44	56 28.66	2.6791	16 24 5.7	0.308	
42	SDM. —18 1269	8.8	3	6.83	56 29.54	2.6306	18 17 27.5	0.307	DM. $8^{\mathrm{M}}.3$
43	SDM. —15 1249	7.5	2	6.67	56 31.47	2.6995	15 35 29.2	0.304	
44	SDM. — 9 1301	9.1	2	6.65	56 40.02	2.8439	9 42 10.0	0.292	
45	SDM. — 9 1303	9.0	2	6.67	56 49.66	2.8562	9 10 43.5	0.278	
46	SDM. — 9 1304	9.3	2	6.69	56 50.64	2.8513	9 23 44.4	0.276	
47	SDM. — 9 1307	8.8	4	6.43	57 13.61	2.8461	9 36 37.6	0.243	
48	SDM. — 9 1308	8.8	3	6.82	57 15.10	2.8439	9 42 5.3	0.240	
49	SDM. —18 1276	8.2	2	6.60	57 24.34	2.6234	18 34 0.6	0.227	
50	SDM. —18 1278	8.8	2	6.65	57 37.40	2.6277	18 23 57.8	0.208	DM. $8^{\mathrm{M}}.5$
51	SDM. — 9 1312	9.2	2	6.65	57 12.87	2.8546	9 15 1.9	0.200	
52	SDM. — 8 1297	9.0	2	6.66	58 9.18	2.8628	8 51 40.0	0.162	DM. $9^{\mathrm{M}}.5$
53	SDM. —19 1335	9.5	2	6.19	58 23.18	2.6121	18 59 58.0	0.111	
54	SDM. — 8 1303	8.4	2	6.66	58 41.90	2.8676	8 12 48.3	0.110	
55	SDM. —18 1287	9.0	2	6.65	59 12.52	2.6205	18 10 39.2	0.069	
56	SDM. — 8 1307	9.2	2	6.65	59 15.84	2.8646	8 49 20.5	0.064	
57	SDM. —18 1289	8.4	2	6.19	59 23.14	2.6121	18 59 54.2	0.054	
58	SDM. —19 1341	9.1	2	6.19	59 32.73	2.6018	19 16 22.4	0.040	
59	SDM. — 9 1321	7.9	2	6.68	59 15.55	2.8539	9 17 1.0	0.021	
60	SDM. —19 1344	9.2	1	6.18	59 51.32	2.6056	19 15 6.4	0.013	
61	SDM. — 8 1312	8.8	2	6.65	59 53.36	2.8619	8 56 32.5	0.010	
62	SDM. —19 1345	8.2	3	7.15	5 59 52.78	2.5995	19 29 1.7	+ 0.010	
63	SDM. — 8 1317	8.4	2	7.19	6 0 45.76	2.8640	8 52 0.8	— 0.067	DM. $9^{\mathrm{M}}.0$
64	SDM. — 8 1319	8.2	2	6.16	0 52.24	2.8765	8 20 24.6	0.076	
65	SDM. — 8 1320	9.2	2	6.13	0 56.38	2.8775	8 17 42.4	0.082	
66	*θ* Leporis		2	6.17	0 59.78	2.7161	11 55 31.5	0.087	U.A. $5^{\mathrm{M}}.2$
67	SDM. — 8 1323	8.5	2	6.16	1 34.52	2.8788	8 11 30.6	0.138	
68	SDM. —19 1355	8.4	3	6.16	1 57.68	2.5877	19 55 32.0	0.172	
69	SDM. —19 1356	9.2	3	6.45	2 4.82	2.6101	19 1 38.2	0.182	DM. $8^{\mathrm{M}}.5$
70	SDM. —21 1353	6.5	2	6.16	2 8.15	2.5377	21 17 59.3	0.187	U.A. $6^{\mathrm{M}}.3$
71	19 Leporis		2	6.17	2 11.26	2.6084	19 9 12.1	0.210	U.A. [illegible]
72	SDM. —19 1364	8.5	2	6.15	3 10.49	2.5923	19 15 28.0	0.278	
73	SDM. —19 1365	8.6	2	6.13	3 12.59	2.6013	19 21 57.6	0.281	
74	SDM. —19 1369	9.5	1	6.18	4 11.76	2.5878	19 55 39.3	0.367	
75	SDM. —20 1297	8.9	3	6.16	4 20.77	2.5683	20 39 15.4	0.380	
76	SDM. —20 1299	8.8	2	6.15	4 27.10	2.5620	20 51 10.6	0.390	
77	SDM. —20 1300	8.9	2	6.15	4 31.18	2.5689	20 38 32.8	0.395	
78	SDM. —20 1303	[8.5]	2	6.60	4 53.02	2.5731	20 28 59.9	0.427	DM. $8^{\mathrm{M}}.0$
79	SDM. —20 1309	9.2	1	6.13	5 18.99	2.5621	20 53 11.0	0.509	
80	SDM. —20 1312	8.8	2	6.61	5 55.92	2.5635	20 50 58.8	0.519	
81	SDM. —21 1383	8.4	3	6.16	6 15.74	2.5175	21 26 15.6	0.592	
82	SDM. — 7 1321	8.0	1	6.24	6 17.38	2.9013	7 17 40.6	0.594	
83	SDM. —21 1384	8.8	2	6.16	6 6 47.92	+2.5539	—21 12 18.0	— 0.595	

No.		Magn.	No. Obs.	Epoch 1880+	α 1886.0	Prec.	δ 1886.0	Prec.	
					h m s	s	° ′ ″	″	
84	SDM. —22 1338	9.3	1	7.12	6 6 58.53	+2.5305	—22 4 35.1	— 0.600	
85	SDM. —21 1385	8.8	2	6.17	7 15.65	2.5327	21 59 45.7	0.635	DM. $9^{\mathrm{M}}.3$
86	SDM. — 7 1325	8.1	3	6.91	7 20.09	2.9019	7 16 16.6	0.612	
87	SDM. —21 1386	8.7	3	6.17	7 41.99	2.5469	21 28 14.8	0.674	
88	SDM. —22 1343	8.9	2	6.61	7 45.31	2.5181	22 32 0.0	0.679	
89	SDM. —21 1387	9.2	2	6.17	7 52.52	2.5401	21 43 18.4	0.689	p.m.?
90	SDM. —21 1389	9.2	3	6.14	8 0.45	2.5327	21 59 52.9	0.700	
91	SDM. — 6 1461	8.0	1	7.19	8 21.16	2.9132	6 47 30.7	0.735	
92	SDM. — 7 1332	6.8	2	6.17	8 26.23	2.9033	7 13 1.5	0.738	
93	SDM. — 6 1470	8.8	2	6.65	9 25.66	2.9128	6 48 46.3	0.825	
94	SDM. —22 1354	8.2	2	6.13	9 46.86	2.5277	22 11 9.8	0.856	
95	SDM. —20 1336	6.8	2	6.16	10 14.22	2.5800	20 14 17.8	0.895	U.A. $6^{\mathrm{M}}.5$
96	SDM. —22 1356	8.6	2	6.18	10 53.30	2.5287	22 9 19.7	0.952	
97		10.0	2	6.75	11 30.24	2.5192	22 30 15.9	1.006	
98	SDM. —22 1361	9.3	2	6.16	11 43.68	2.5201	22 28 5.5	1.027	
99	SDM. —22 1362	8.8	1	6.19	11 47.66	2.5215	22 25 19.1	1.032	DM. $9^{\mathrm{M}}.4$
100	SDM. —22 1364	7.0	2	6.15	12 15.80	2.5149	22 39 58.5	1.073	p.m. Stone
101	SDM. —22 1365	7.6	3	6.17	12 20.13	2.5240	22 19 59.1	1.079	
102	SDM. — 6 1487	6.9	3	6.93	12 35.77	2.9160	6 41 1.9	1.102	
103	SDM. — 6 1491	9.0	2	6.16	13 52.86	2.9225	6 24 24.9	1.214	
104	SDM. — 6 1492	9.1	1	6.18	13 56.60	2.9229	6 23 28.3	1.219	
105	SDM. —22 1374	9.1	2	6.15	14 3.26	2.5113	22 48 33.4	1.229	
106	SDM. —20 1355	6.8	2	6.16	14 6.71	2.5633	20 52 48.9	1.234	U.A. $6^{\mathrm{M}}.2$
107	SDM. —22 1377	9.2	3	6.51	14 25.27	2.5067	22 58 38.3	1.261	
108	SDM. —22 1381	8.6	2	6.63	14 59.00	2.5164	22 37 38.0	1.310	
109	SDM. — 6 1504	8.6	2	6.17	15 9.52	2.9259	6 15 58.4	1.325	
110	Oe. A. 4972	8.6	2	6.16	15 19.90	2.5047	23 3 23.0	1.341	
111		9.4	1	6.14	15 22.35	2 5050	23 2 41.9	1.344	
112	Yar. 2608	7.2	2	6.15	15 51.48	2.4903	23 35 7.2	1.386	
113		9.2	2	6.61	17 14.18	2.4968	23 21 13.0	1.507	
114		8.9	1	6.19	17 23.90	2.5000	23 14 24.7	1.521	
115	C.Z. 793	8.2	2	6.16	17 40.14	2.4919	23 32 10.7	1.545	
116	SDM. —5°1629	8.4	2	6.17	19 32.89	2.9374	5 47 22.8	1.708	
117	A.G.C. 7785	9.4	2	6.16	19 42.62	2.4844	23 48 48.8	1.723	
118	C.Z. 971	9.1	2	6.16	21 28.61	2.4635	24 35 13.3	1.876	
119	Oe. A. 5135	8.3	2	6.16	22 42.20	2.4742	24 12 34.0	1.983	
120	Oe. A. 5277	9.0	2	6.16	28 31.28	2.4517	25 4 54.4	2.489	
121		9.7	1	6.21	28 43.45	2.4526	25 2 44.6	2.507	
122	SDM. —5°1694	9.3	3	6.47	29 31.78	2.9457	5 27 58.6	2.581	
123	SDM. —5 1695	8.6	2	6.68	29 36.55	2.9448	5 29 53.6	2.584	
124	SDM. —5 1697	9.2	2	6.68	29 54.62	2.9355	5 53 47.2	2.610	
125	C.Z. 1393	8.4	2	6.17	30 35.66	2.4333	25 44 58.0	2.669	
126	C.Z. 1492	8.4	2	6.16	32 26.97	2.4293	25 55 16.6	2.830	
127	C.Z. 1550	8.4	2	6.16	33 40.88	2.4268	26 1 14.2	2.937	
128	C.Z. 1588	9.0	2	6.17	34 33.84	2.4309	25 53 35.0	3.013	
129	C.Z. 1592	9.1	2	6.20	34 35.60	2.4204	26 15 47.9	3.016	
130	C.Z. 1606	8.7	1	6.14	34 52.10	2.4191	26 18 39.0	3.039	
131	C.Z. 1638	8.2	2	6.16	35 19.52	2.4085	26 41 2.4	3.079	
132	C.Z. 1669	8.4	2	6.16	35 52.41	2.4224	26 12 17.0	3.126	
133		9.4	2	6.20	38 37.76	2.4084	26 44 32.6	3.364	
134	C.Z. 1821	8.3	2	6.16	38 44.02	2.4195	26 21 25.1	3.373	
135	C.Z. 1909	7.2	3	6.18	40 18.93	2.3949	27 14 1.4	3.509	p.m. Kreutz
136	A.G.C. 8444	10.2	2	6.16	43 9.62	2.4072	26 53 44.4	3.754	
137	C.Z. 2115	9.0	2	6.17	43 41.06	2.4056	26 56 34.8	3.799	
138	C.Z. 2137	8.0	2	6.17	44 1.59	2.3963	27 15 12.6	3.829	
139	Yar. 2748	7.8	3	6.19	44 6.86	2.3720	28 5 14.3	3.836	
140	C.Z. 2150	8.9	1	6.15	44 16.14	2.3968	27 14 16.2	3.850	
141	C.Z. 2228	7.5	2	6.16	45 32.49	2.3987	27 12 9.0	3.959	
142	C.Z. 2374	8.8	2	6.17	48 1.05	2.3878	27 38 2.3	4.171	p.m.?
143	C.Z. 2404	6.5	2	6.16	48 25.44	2.4117	26 48 58.7	4.206	
144	C.Z. 2423	9.0	2	6.17	48 44.70	2.3855	27 43 44.2	4.233	
145	C.Z. 2429	8.4	2	6.17	6 48 56.50	+2.3864	—27 42 24.3	— 4.250	

No.		Magn.	No. Obs.	Epoch 1880+	α 1886.0	Prec.	δ 1886.0	Prec	
					h m s	s	° ′ ″	″	
146	C.Z. 2463	8.3	2	6.16	6 49 29.42	+2.3895	—27 37 5.6	— 4.297	
147	C.Z. 2495	8.8	2	6.21	50 0.10	2.3954	27 24 56.0	4.341	
148	C.Z. 2523	9.0	1	6.19	50 32.08	2.3794	27 58 29.8	4.386	
149		9.7	3	6.18	51 51.37	2.3827	27 53 23.4	4.499	
150		9.6	4	6.71	52 59.84	2.3810	27 59 3.8	4.596	
151	C.Z. 2808	8.5	2	6.16	55 2.78	2.3896	27 44 3.9	4.771	
152	C.Z. 2819	7.8	2	6.21	55 13.82	2.3749	28 14 31.6	4.786	
153	C.Z. 2848	8.8	3	6.20	55 41.91	2.3695	28 26 52.5	4.830	
154	Yar. 2834	6.6	2	6.21	56 12.19	2.3734	28 19 40.2	4.869	
155	σ Canis Maj.		2	6.17	57 10.68	2.3902	27 46 20.8	4.952	U.A. $3^{M}.6$
156	C.Z. 2994	8.9	2	6.16	57 41.56	2.3700	28 28 14.7	4.995	
157		9.2	2	6.17	58 27.84	2.3714	28 27 19.0	5.060	
158	C.Z. 3125	9.1	2	6.16	6 59 54.42	2.3616	28 43 37.4	5.183	
159	C.Z. 38	8.7	2	6.16	7 1 0.28	2.3605	28 53 19.6	5.275	
160	A.G.C. 9006	8.8	2	6.16	3 12.16	2.3649	28 48 45.8	5.460	
161		8.2	2	6.16	4 2.98	2.3766	28 26 0.5	5.546	
162	C.Z. 279	8.2	2	6.20	4 20.38	2.3653	28 50 11.2	5.556	
163		9.2	1	6.18	5 25.55	2.3583	29 6 20.2	5.648	
164	C.Z. 386	8.2	3	6.19	6 1.58	2.3572	29 9 41.0	5.698	
165		9.1	3	6.19	7 2.02	2.3547	29 16 41.5	5.782	
166	C.Z. 574	8.2	2	6.16	8 58.24	2.3650	28 59 18.9	5.944	
167	Oe.A. 6475	7.8	2	6.16	10 21.65	2.3729	28 46 0.6	6.065	
168		10.2	2	6.71	11 19.08	2.3585	29 17 26.2	6.140	
169	C.Z. 757	8.9	3	6.17	11 31.49	2.3587	29 17 30.8	6.158	
170	C.Z. 762	9.3	3	6.46	11 33.37	2.3588	29 17 13.2	6.160	
171		8.5	2	6.15	12 31.10	2.3528	29 31 37.0	6.240	
172	C.Z. 881	8.6	2	6.20	13 12.84	2.3599	29 18 27.4	6.298	
173		9.0	1	6.18	13 11.02	2.3525	29 33 13.6	6.300	
174	A.G.C. 9304	8.3	2	6.15	13 49.09	2.3497	29 40 40.6	6.348	
175	C.Z. 1109	8.3	2	6.16	16 21.75	2.3532	29 38 59.4	6.559	
176	C.Z. 1270	7.9	2	6.16	18 29.06	2.3591	29 31 55.4	6.734	
177	A.G.C. 9166	8.0	2	6.47	19 13.86	2.3395	30 13 43.9	6.796	
178	C.Z. 1341	6.8	2	6.16	19 26.96	2.3466	29 59 45.1	6.814	
179	C.Z. 1373	8.9	2	6.17	19 49.46	2.3491	29 55 26.6	6.845	
180	A.G.C. 9502	9.4	2	6.22	20 22.20	2.3542	29 16 19.0	6.889	
181	A.G.C. 9526	8.9	3	6.17	20 50.05	2.3550	29 45 52.5	6.927	
182	C.Z. 1597	8.6	2	6.22	21 41.65	2.3477	30 2 53.6	6.998	
183	A.G.C. 9580	9.8	3	6.20	23 5.04	2.3535	29 53 22.8	7.112	
184	A.G.C. 9597	8.6	2	6.18	23 38.96	2.3690	29 23 30.4	7.158	
185	C.Z. 1648	9.0	3	6.21	23 47.11	2.3546	29 53 34.3	7.169	
186		9.0	1	6.21	24 16.01	2.3545	29 56 23.5	7.249	
187	C.Z. 1735	9.1	3	6.16	25 7.22	2.3524	30 1 24.8	7.278	
188	C.Z. 1743	8.9	2	6.21	25 15.48	2.3546	29 57 18.4	7.289	
189	C.Z. 1826	8.3	1	6.18	26 30.59	2.3464	30 18 1.0	7.391	
190	C.Z. 1851	8.4	2	6.47	26 48.21	2.3471	30 16 10.3	7.405	
191	C.Z. 1860	8.1	3	6.18	26 52.08	2.3505	30 9 16.5	7.420	
192	C.Z. 2039	8.4	3	6.17	29 17.19	2.3543	30 8 29.7	7.647	
193	C.Z. 2405	8.9	2	6.16	34 19.18	2.3592	30 12 9.8	8.023	
194	C.Z. 2515	9.3	3	6.27	35 12.43	2.3596	30 15 25.3	8.133	
195	C.Z. 2827	8.6	2	6.16	39 37.96	2.3455	30 56 38.4	8.446	
196	C.Z. 2844	9.2	2	6.21	39 47.60	2.3733	29 58 19.1	8.459	
197	C.Z. 2847	8.1	3	6.49	39 50.70	2.3739	29 57 39.7	8.463	
198	A.G.C. 10094	9.2	3	6.16	40 12.30	2.3642	30 20 16.8	8.534	
199	C.Z. 3497	7.6	3	6.16	44 6.87	2.3655	30 28 19.0	8.800	
200	C.Z. 3735	6.8	2	6.16	50 43.64	2.3718	30 3[illegible] 5.4	9.316	
201	C.Z. 4078	8.4	2	6.15	54 13.33	2.3812	30 30 17.0	9.625	
202	C.Z. 4290	7.5	1	6.15	57 2.20	2.3916	30 16 34.3	9.802	
203	C.Z. 4296	7.8	2	6.15	57 3.22	2.3907	30 18 18.2	9.803	
204		9.3	3	6.17	7 59 19.25	2.3853	30 38 50.2	9.976	
205	A.G.C. 10718	8.8	2	6.15	8 0 58.96	2.3929	30 28 33.7	10.101	
206	C.Z. 120	8.8	2	6.20	1 58.96	2.3945	30 29 0.1	10.177	
207		9.3	1	6.18	8 2 11.39	+2.3945	—30 29 13.2	—10.193	

No.		Magn.	No. Obs.	Epoch 1880+	α 1886.0	Prec.	δ 1886.0	Prec
					h m s	s	° ′ ″	″
208	C.Z. 237	8.8	2	6.17	8 3 33.66	+2.3973	—30 28 18.2	—10.296
209	C.Z. 241	8.6	2	6.17	3 36.06	2.3978	30 27 36.3	10.299
210	C.Z. 275	9.1	2	6.20	4 3.03	2.3939	30 37 15.2	10.333
211	C.Z. 441	8.8	3	6.17	5 59.85	2.3991	30 34 15.1	10.478
212	A.G.C. 10911	9.3	2	6.22	7 34.08	2.4038	30 29 55.4	10.595
213		9.2	3	6.64	8 15.15	2.4056	30 28 51.7	10.616
214	C.Z. 811	8.1	2	6.20	10 26.02	2.4087	30 30 34.8	10.807
215	C.Z. 875	8.6	2	6.21	11 11.16	2.4116	30 27 41.7	10.862
216	C.Z. 891	6.8	2	6.22	11 18.32	2.4087	30 34 33.8	10.871
217	C.Z. 894	8.4	1	6.19	11 20.84	2.4113	30 28 45.1	10.874
218	C.Z. 993	8.8	2	6.22	12 32.80	2.4147	30 25 46.5	10.962
219		8.9	2	6.21	13 38.48	2.4182	30 22 52.6	11.042
220	C.Z. 1241	7.8	2	6.20	15 29.92	2.4123	30 44 17.9	11.178
221	C.Z. 1319	8.8	2	6.20	16 29.77	2.4276	30 13 21.6	11.250
222	C.Z. 1534	8.0	2	6.20	18 54.00	2.4270	30 26 5.0	11.424
223	C.Z. 1541	9.3	1	6.23	8 19 3.23	2.4367	—30 3 53.5	—11.435

(*Conclusion follows in no. 227.*)

NEW ASTRONOMICAL WORKS.

Observations de Poulcova, publiées par Otto Struve, *Directeur de l'Observatoire Central Nicolas.* Vol. VIII, *Catalogues d' Etoiles, deduits des observations publiées dans les* Vols. VI *et* VII. 1889.

This important volume contains the final results deduced from the observations made with the Repsold meridian-circle during the years 1849 to 1869, and published in volumes VI and VII of the Pulkowa series.

The original programme of the elder Struve provided that the meridian-circle should be devoted to the reobservation of all of Bradley's stars, north of the parallel of —15°, together with such additional ones, down to the sixth magnitude, as had been included by Argelander in his Uranometry; each star being observed in four different positions of the instrument, viz.: with the object-glass at each end of the tube both for Clamp East and Clamp West. For the right-ascensions, he had intended that the positions of the fundamental stars should be those of Bessel, but the positions determined with the large Pulkowa transit-instrument were afterwards substituted. So too, for the declinations, those of the principal stars, as determined with the Ertel vertical circle have been adopted as fundamental, and the whole system referred to these.

The preface to the volume contains a detailed account of the observations and of their computation, with full reference to the especial labors of the several astronomers who took part in the work.

The series of catalogues begins with the positions for 1855.0 of the 380 stars which form the fundamental system to which the other catalogues are referred. These are deduced from a combination of the Pulkowa fundamental catalogues for 1845 and 1865, according to rules which are fully set forth. To these positions are appended, for each coordinate, two terms of the annual precession and the proper motion of the star according to Auwers's latest determinations.

Next follows Section I, which shows the results of each separate observation, reduced to the epoch and equinox of 1855.0. They are divided into four belts, according to declination; and in each have been applied the small corrections requisite for referring them to the mean of the four positions of the instrument and to the mode of observation of the principal observer in the belt. With each declination is given, in smaller type, the total amount of the reductions thus applied to the value given in volume VI and VII.

The accidental errors of observation are given as varying between the limits ±0s.056 and ±0s.082, according to the declination, and between ±0″.42 and ±0″.65 for different observers and declinations; so that those of the catalogue-places deduced from observations made in the four positions of the instrument are inferred to be from 0s.03 to 0s.04 and 0″.26.

Section II consists of the resultant catalogue of 3542 stars; and in this, the means of the positions given in Section I are slightly modified, in order to reduce them to the fundamental system. Two terms of the annual precession are given for each coordinate, as well as the values adopted for the proper motion.

Section III contains a catalogue of 1404 other stars, which have been incidentally observed, although not belonging to the original programme. Among these are numerous stars which have served for comparison with comets and asteroids, as well as some double stars, and others yet which have been determined for special purposes. This catalogue also is referred to the fundamental system, and gives the annual precessions.

An Appendix shows the several values for the declination of the 380 principal stars, as deduced for each of the four observers in each of the four positions of the instrument; and likewise contains a list of corrections for each of the three volumes, VI, VII and VIII.

The volumes of the Pulkowa series have now been published to XIV inclusive, with the exception of X. The preface to this vol. VIII bears the date February 1889; and the volume forms a noble close for the administration of Mr. Otto Struve.

Publications of Carleton College Observatory, I. — *Catalogue of 644 Comparison-stars, observed during the years 1887 to 1889 and prepared for publication, under the direction of* William W. Payne, *Professor of Mathematics and Astronomy and Director of the Observatory, by* Herbert C. Wilson, *Ph.D., Assistant Professor of Astronomy.* Northfield, Minn., 1890.

The greater part of the stars here observed are comparatively faint ones, near to nebulas, the positions of which had been determined by micrometric comparison with them by Prof. Ormond Stone, at the University of Virginia. There are also a few which have been used as comparison-stars in observations of comets. The individual observations are given, as well as their mean, all being referred to the mean equinox of 1890.0.

The meridian circle, made by Repsold & Sons in 1885, is described in the Introduction, as also the methods employed for determining the corrections.

Dr. Wilson gives the probable errors, for a night's observation, as ranging between ±0s.02 and ±0″.4, for stars between 6M and 7M, to ±0s.10 and ±0″.9 for those between 9½M and 10M.

To the catalogue is appended a table of the deduced positions of 87 time-stars, and a comparison of these with the places given in the *Berliner Jahrbuch.*

CONTENTS.

The Secular Variation of the Motion of the Moon's Perigee, by Prof. G. W. Hill.
Observations of the Satellites of Mars in 1890, by Prof. A. Hall.
Positions of 465 Comparison-Stars Determined at Albany, by Prof. Lewis Boss.
New Astronomical Works.

Published in Boston, semi-monthly, by B. A. Gould. Address, Cambridge, Mass. Price, $5.00 the volume. Press of Thos. P. Nichols, Lynn, Mass.
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No. 227.

VOL. X. BOSTON, 1890 OCTOBER 18. NO. 11

POSITIONS OF 465 COMPARISON-STARS DETERMINED AT ALBANY.

BY LEWIS BOSS.

(Concluded from no. 226.)

No.		Magn.	No. Obs.	Epoch 1880+	α 1886.0	Prec.	δ 1886.0	Prec.	
					h m s	s	° ′ ″	″	
224	C.Z. 1543	8.0	2	6.23	8 19 4.14	+2.4378	−30 1 32.0	−11.436	
225	C.Z. 1611	9.0	3	6.54	19 52.12	2.4327	30 17 12.5	11.493	
226	C.Z. 1614	9.1	2	6.71	19 54.20	2.4326	30 17 21.5	11.496	
227	C.Z. 1983	8.2	2	6.21	24 12.00	2.4589	29 34 20.4	11.802	
228	C.Z. 2000	8.4	2	6.22	24 19.65	2.4367	30 28 12.9	11.811	
229	C.Z. 2025	8.4	2	6.21	24 38.60	2.4494	29 59 16.2	11.833	p.m.?
230	C.Z. 2068	8.2	2	6.22	25 12.40	2.4516	29 56 40.4	11.873	
231	A.G.C. 11514	8.9	2	6.21	28 55.41	2.4611	29 51 21.4	12.133	
232	A.G.C. 11527	9.0	2	6.23	29 7.44	2.4607	29 53 22.0	12.147	
233	C.Z. 2130	9.0	2	6.21	29 33.08	2.4646	29 46 55.0	12.177	
234	C.Z. 2595	8.2	2	6.22	31 33.80	2.4583	30 12 9.5	12.316	
235	C.Z. 2603	8.5	2	6.23	31 42.70	2.4723	29 38 40.6	12.327	
236	C.Z. 2765	8.4	2	6.22	33 39.64	2.4779	29 35 8.0	12.461	
237	ξ Pyxidis		2	6.22	34 58.60	2.4908	29 9 21.2	12.551	U.A. 5^M.4
238	C.Z. 3108	8.4	2	6 22	38 19.12	2.4986	29 6 53.2	12.778	
239	C.Z. 3401	7.2	3	6.22	41 49.83	2.5005	29 20 29.1	13.013	
240	C.Z. 3403	7.5	2	6.23	41 51.14	2.5013	29 18 40.4	13.014	
241	C.Z. 3476	8.8	2	6.22	42 46.14	2.5046	29 15 10.2	13.075	
242	C.Z. 3671	8.8	2	6.22	45 15.50	2.5147	29 2 20.8	13.240	
243	W.M.Z. 102.56	9.0	2	6.23	45 36.06	2.5200	28 50 45.5	13.262	
244	C.Z. 3811	8.6	2	6.22	47 0.62	2.5188	29 2 6.6	13.354	
245	C.Z. 3828	9.0	2	6 23	47 15.26	2.5200	28 59 58.6	13.370	
246	A.G.C. 12100	9.2	2	6.22	49 20.82	2.5301	28 45 25.4	13.506	
247	C.Z. 4158	8.6	2	6.22	51 30.52	2.5290	29 0 55.8	13.645	
248	C.Z. 4169	8.0	2	6 23	51 39.95	2.5319	28 54 28.9	13.656	
249	C.Z. 4175	9.0	2	6.23	51 52.12	2.5354	28 46 0.2	13.669	
250	C.Z. 4180	[9.4]	2	6.24	51 58.54	2.5385	28 38 32.7	13.675	
251	C.Z. 4266	8.6	2	6.22	53 7.98	2.5458	28 25 51.0	13.749	
252	C.Z. 4367	7.0	3	6.23	54 25.44	2.5498	28 21 51.1	13.831	
253	C.Z. 4427	8.8	3	6.23	55 11.08	2.5484	28 30 29.9	13.883	
254		[9.5]	1	6 23	55 17.58	2.5804	27 2 46.8	13.886	
255	Yar. 3808	7.0	2	6 22	56 11.88	2.5813	27 4 9.5	13.943	
256	C.Z. 4514	8.9	2	6.25	56 15.60	2.5633	27 55 18.5	13.947	
257	C.Z. 4530	8.3	2	6.25	56 21.03	2.5533	28 23 16.4	13.956	
258	A.G.C. 12308	9.0	2	6 22	57 26.28	2.5610	28 8 53.8	14.021	
259	A.G.C. 12337	9.5	2	6 23	8 58 31.34	2.5661	28 1 7.8	14.089	
260	C.Z. 4833	7.0	2	6.22	9 0 15.14	2.5583	28 33 49.8	14.196	
261		9.5	3	6.25	2 46.66	2.5855	27 32 39.7	14.354	
262		9.1	2	6.76	2 49.46	2.5645	28 32 39.6	14.354	
263	C.Z. 199	8.0	2	6.23	2 54.26	2.5816	27 44 21.0	14.359	
264	C.Z. 239	8.6	2	6.22	3 20.04	2.5766	28 1 31.4	14.385	
265	C.Z. 320	8.2	3	6.23	4 13.82	2.5853	27 42 13.4	14.410	
266		9.6	3	6.23	5 36.18	2.5881	27 42 46.0	14.523	
267	C.Z. 437	8.9	3	6.32	5 37.97	2.5884	27 43 40.9	14.525	
268	C.Z. 469	8.8	2	6.23	6 8.57	2.6044	26 58 31.4	14.555	
269	C.Z. 518	8.0	2	6.22	9 6 56.30	+2.5884	−27 50 57.8	−14.603	

No.		Magn.	No. Obs.	Epoch 1880+	α 1886.0	Prec.	δ 1886.0	Prec.	
					h m s	s	° ′ ″	″	
270	Oe.A. 9157	9.3	3	6.25	9 7 23.07	+2.6016	−27 11 39.2	−14.650	
271	C.Z. 651	7.9	2	6.24	8 46.75	2.5925	27 50 5.4	14.713	
272	A.G.C. 12561	9.0	4	6.26	9 1.36	2.6091	27 2 11.8	14.728	
273	C.Z. 690	[9.2]	2	6.24	9 16.58	2.6120	26 55 13.8	14.743	
274	C.Z. 835	8.5	3	6.24	10 59.87	2.6199	26 43 17.6	14.844	
275	C.Z. 1008	8.7	3	6.23	13 9.12	2.6230	26 18 13.3	14.970	
276	W.M.Z. 244.2	9.0	2	6.24	15 4.02	2.6380	26 11 21.8	15.081	
277	C.Z. 1162	8.5	2	6.22	15 6.50	2.6356	26 22 14.0	15.084	
278		9.2	2	6.24	15 16.06	2.6331	26 31 30.8	15.093	
279	θ Pyxidis		3	6.23	16 26.79	2.6554	25 28 50.8	15.161	U.A. $5^{M}.2$
280	C.Z. 1296	8.3	2	6.24	16 42.43	2.6518	25 41 48.0	15.176	
281	C.Z. 1427	8.2	2	6.23	18 19.82	2.6557	25 40 40.8	15.268	
282		9.1	2	6.24	18 40.36	2.6595	25 29 9.2	15.288	
283		9.3	2	6.26	18 47.57	2.6596	25 31 15.2	15.294	
284		9.5	2	6.25	20 10.71	2.6541	25 58 21.8	15.373	
285		9.0	2	6.26	20 20.78	2.6660	25 21 15.7	15.382	
286		9.4	2	6.28	21 9.90	2.6542	26 4 16.4	15.419	
287	C.Z. 1699	8.9	2	6.24	21 36.21	2.6553	26 5 0.0	15.452	
288		9.2	2	6.23	22 21.50	2.6713	25 17 15.6	15.494	
289	C.Z. 1778	8.8	2	6.24	22 39.88	2.6618	25 57 56.1	15.511	
290	C.Z. 1830	8.0	2	6.25	23 21.18	2.6642	25 48 5.1	15.549	
291	C.Z. 1849	[8.5]	2	6.22	23 36.86	2.6638	25 51 2.6	15.564	
292	C.Z. 1940	7.0	2	6.22	24 37.40	2.6614	26 5 38.7	15.619	p.m.
293	C.Z. 1945	8.0	2	6.24	24 40.10	2.6810	25 1 42.6	15.622	
294	C.Z. 1960	6.0	2	6.22	24 50.92	2.6624	26 5 25.0	15.632	
295		9.0	2	6.24	25 7.50	2.6733	25 30 59.9	15.647	
296	C.Z. 2027	7.5	2	6.24	25 35.18	2.6815	25 6 54.0	15.672	
297	C.Z. 2074	8.1	4	6.28	26 11.48	2.7051	23 50 30.8	15.705	
298		10.0	3	6.26	26 14.38	2.6779	25 23 7.6	15.708	
299	C.Z. 2148	9.0	2	6.25	27 3.56	2.6849	25 5 13.2	15.752	
300	C.Z. 2333	[8.6]	2	6.22	29 18.95	2.7081	24 1 17.4	15.874	
301	C.Z. 2348	8.1	2	6.24	29 32.86	2.6982	24 38 25.5	15.886	
302	Oe.A. 9870	9.0	2	6.24	29 34.92	2.6951	24 49 15.8	15.888	
303	Oe.A. 9893	9.0	2	6.22	30 39.68	2.7056	24 20 40.8	15.945	
304	Oe.A. 9910	8.7	2	6.24	31 20.88	2.7176	23 43 1.0	15.982	
305	C.Z. 2488	6.9	3	6.26	31 25.53	2.7097	24 11 40.2	15.986	
306	C.Z. 2525	[6.4]	2	6.22	31 52.56	2.7005	24 47 13.2	16.009	
307	DM. —0°2229	8.2	2	6.24	32 24.03	3.0590	0 57 46.8	16.037	
308	SDM. —22°2673	[8.5]	2	6.20	33 53.36	2.7415	22 34 51.5	16.115	DM. $7^{M}.3$ [$3^{M}.9$
309	ι Hydrae		4	6.24	34 2.04	3.0639	0 37 33.7	16.122	p.m.Auwers. U.A.
310	C.Z. 2789	8.7	2	6.23	35 45.85	2.7281	23 38 3.4	16.212	
311	C.Z. 2811	8.9	2	6.25	36 0.56	2.7324	23 23 51.4	16.225	
312	C.Z. 2817		2	6.27	36 5.00	2.7378	23 4 25.4	16.228	U.A. $5^{M}.2$
313	Oe.A. 10034	8.2	4	6.50	36 50.01	2.7283	23 45 16.0	16.267	
314	C.Z. 2871	8.5	2	6.26	36 55.90	2.7377	23 11 19.8	16.272	
315		9.2	1	6.30	37 3.11	2.7290	23 44 37.5	16.278	[$5^{M}.4$
316	C.Z. 2880		3	6.27	37 5.77	2.7346	23 24 11.8	16.280	p.m. Kreutz. U.A.
317	SDM. —22°2693	8.6	2	6.23	37 37.96	2.7510	22 26 15.0	16.308	DM. $7^{M}.8$
318	SDM. —22 2704	8.8	3	6.25	39 5.14	2.7500	22 41 32.9	16.381	
319	SDM. —22 2705	8.4	2	6.26	39 22.32	2.7578	22 13 46.8	16.396	DM. $6^{M}.8$
320	SDM. —22 2706	8.1	2	6.24	39 23.56	2.7482	22 50 15.6	16.397	p.m.?
321	SDM. —22 2707	8.2	2	6.25	39 26.24	2.7449	23 2 59.0	16.399	
322	C.Z. 3049	8.0	3	6.58	39 42.80	2.7471	22 57 37.2	16.413	
323	C.Z. 3078	9.2	2	6.25	40 1.88	2.7379	23 34 17.4	16.429	
324		8.8	1	7.23	40 26.89	2.7402	23 28 6.9	16.450	
325	SDM. —21°2904	7.8	4	6.27	41 2.54	2.7626	22 7 38.6	16.480	
326	SDM. —22 2725	9.4	2	6.24	41 37.62	2.7580	22 30 30.8	16.509	
327	SDM. —21 2907	8.0	2	6.25	41 51.42	2.7786	21 10 27.6	16.520	
328	SDM. —22 2722	9.2	2	6.25	43 5.68	2.7654	22 12 34.5	16.581	
329	SDM. —22 2725	8.1	3	6.25	43 19.22	2.7668	22 9 3.3	16.592	
330	SDM. —21 2912	8.0	3	6.27	43 32.79	2.7772	21 29 20.7	16.603	DM. $7^{M}.2$
331	DM. — 0 2256	8.2	2	6.30	9 44 35.52	+3.0610	— 0 53 27.0	−16.655	

No.		Magn	No. Obs.	Epoch 1880+	α 1886.0	Prec.	δ 1886.0	Prec.	
					h m s	s	° ′ ″	″	
332	SDM. —22°2733	10.5	1	7.23	9 44 40.78	+2.7672	—22 17 45.1	—16.659	Rough Obs. DM.
333	SDM. —22 2739	[6.0]	2	6.26	45 47.96	2.7666	22 29 1.9	16.713	DM. $6^{M}.6$ $9^{M}.8$
334	SDM. —22 2741	[9.0]	2	6.27	45 59.06	2.7678	22 25 46.2	16.722	DM. $8^{M}.8$
335	SDM. —22 2742	9.2	1	6.27	46 12.11	2.7614	22 52 20.4	16.733	
336	SDM. —22 2746	9.6	3	6.57	46 43.84	2.7735	22 8 38.7	16.758	
337	SDM. —21 2928	[9.5]	2	6.24	47 39.76	2.7861	21 24 16.8	16.803	
338	SDM. —21 2931	9.2	2	6.21	48 25.18	2.7894	21 18 29.5	16.839	
339	SDM. —21 2935		2	6.24	49 11.70	2.7814	21 56 57.1	16.878	U.A. $6^{M}.5$
340	SDM. —18 2810		2	6.23	49 29.62	2.8317	18 28 10.6	16.890	p.m.? U.A. $5^{M}.6$
341	SDM. —21 2941	8.0	2	6.25	49 48.35	2.7817	21 47 45.6	16.904	
342	SDM. —19 2864	9.3	1	6.28	50 5.26	2.8166	19 37 10.4	16.918	
343	SDM. —19 2865	8.6	2	6.27	50 7.01	2.8192	19 26 22.6	16.919	DM. $8^{M}.0$
344	SDM. —20 3049	8.2	2	6.25	50 25.96	2.8090	20 12 11.6	16.934	p.m.?
345	SDM. —20 3051	9.0	2	6.25	50 34.78	2.7985	20 57 9.7	16.941	
346	SDM. —20 3052	8.6	3	6.19	51 14.25	2.8031	20 12 49.3	16.971	
347	SDM. —20 3059	8.1	1	6.26	52 26.71	2.8067	20 38 17.4	17.028	
348	SDM. —20 3062	9.0	3	6.26	53 9.82	2.8107	20 26 49.6	17.061	
349	SDM. —19 2883	8.6	2	6.23	53 56.61	2.8233	19 37 41.0	17.096	DM. $8^{M}.0$
350	SDM. —19 2884	7.0	2	6.22	53 57.08	2.8208	19 48 41.5	17.097	U.A. $6^{M}.8$
351	SDM. —18 2827	8.8	2	6.22	55 57.29	2.8336	19 7 36.0	17.188	
352	SDM. —20 3074	9.0	2	6.21	56 20.75	2.8167	20 25 2.8	17.205	
353	SDM. —19 2895	9.3	2	6.23	56 48.41	2.8337	19 13 3.3	17.226	Double. DM. $8^{M}.6$
354	SDM. —19 2897	7.5	3	6.26	57 11.51	2.8257	19 52 24.9	17.246	
355	SDM. —20 3083	8.9	2	6.26	57 31.62	2.8206	20 16 52.1	17.258	
356	SDM. —19 2899	9.3	2	6.24	57 33.18	2.8351	19 11 22.9	17.260	
357	SDM. —20 3088	8.2	3	6.27	57 51.31	2.8199	20 22 47.2	17.273	
358	SDM. —17 3046	7.4	2	6.35	58 35.41	2.8589	17 32 58.0	17.306	
359	SDM. —17 3047	6.5	2	6.35	58 36.93	2.8592	17 32 59.6	17.307	
360	SDM. —19 2902	9.2	2	6.24	58 37.07	2.8356	19 21 8.9	17.307	
361	SDM. —18 2834	8.6	2	6.26	58 54.33	2.8418	18 53 23.5	17.319	
362	SDM. —18 2835	8.2	2	6.22	59 1.87	2.8424	18 51 37.4	17.325	
363	SDM. —20 3091	8.7	2	6.24	9 59 58.42	2.8181	20 48 7.2	17.366	
364	SDM. —18 2844	8.7	2	6.22	10 1 13.48	2.8476	18 45 6.8	17.421	p.m.
365		8.8	2	6.22	1 13.88	2.8476	18 45 13.3	17.421	
366	SDM. —16 2969	7.0	2	6.24	1 26.51	2.8717	16 53 20.4	17.430	
367	SDM. —19 2915	9.0	2	6.26	1 36.09	2.8418	19 14 55.9	17.437	
368	SDM. —16 2973	7.9	2	6.27	1 38.32	2.8714	16 55 41.4	17.439	
369	SDM. —16 2974	[6.3]	2	6.27	1 41.32	2.8759	16 35 3.6	17.441	U.A $6^{M}.0$ DM. 5^{M}
370	SDM. —20 3104	7.7	3	6.28	1 44.99	2.8232	20 42 0.8	17.443	
371	SDM. —19 2918	8.2	2	6.26	1 58.06	2.8438	19 9 12.2	17.453	DM. $7^{M}.2$
372	SDM. —18 2848	8.9	2	6.28	2 12.78	2.8471	19 0 27.8	17.485	DM. $8^{M}.0$
373	SDM. —17 3068	8.4	2	6.23	2 54.46	2.8618	17 51 42.6	17.493	
374	SDM. —19 2926	8.2	2	6.27	2 57.96	2.8451	19 11 15.6	17.496	p.m. DM. $7^{M}.2$
375	SDM. —14 3036	7.2	2	6.26	3 5.34	2.8968	15 3 16.6	17.500	DM. $6^{M}.5$
376	SDM. —17 3070	8.5	2	6.28	3 12.51	2.8612	17 56 43.4	17.506	
377	SDM. —14 3039	8.2	2	6.27	3 38.36	2.8990	14 55 18.0	17.525	p.m. DM. $7^{M}.5$
378	SDM. —17 3071	8.8	2	6.28	3 43.90	2.8661	17 37 38.4	17.528	
379	SDM. —17 3072	7.8	3	6.27	3 48.67	2.8569	17 34 46.1	17.532	p.m. DM. $7^{M}.2$
380	SDM. —12 3101		2	6.25	4 32.52	2.9322	12 15 9.9	17.563	U.A. $5^{M}.9$
381	SDM. —18 2853	8.6	2	6.27	4 32.34	2.8589	18 18 16.2	17.563	$3^{M}.1$
382	λ Hydrae		2	6.27	5 1.84	2.9382	11 47 27.9	17.583	p.m. Auwers. U.A.
383	SDM. —17 3078	7.8	3	6.49	5 7.85	2.8631	18 2 35.0	17.588	
384	SDM. —14 3046	7.8	2	6.27	5 21.68	2.8988	15 8 56.4	17.597	DM. $7^{M}.2$
385	SDM. —16 2987	8.1	2	6.27	5 28.44	2.8843	16 22 41.9	17.602	DM. $7^{M}.5$
386	SDM. —17 3082	9.0	2	6.28	5 41.83	2.8717	17 25 51.8	17.613	
387	SDM. —16 2989	[8.0]	3	6.29	5 49.64	2.8762	17 4 28.4	17.617	DM. $7^{M}.7$
388	SDM. —18 2861	7.5	2	6.26	5 52.60	2.8601	18 23 37.3	17.619	p.m.
389	SDM. —17 3083	8.5	3	6.30	5 53.71	2.8684	17 13 31.0	17.620	DM. $9^{M}.0$
390	SDM. —13 3055	8.5	2	6.23	6 2.08	2.9168	13 12 46.1	17.625	DM. $8^{M}.0$
391	SDM. —16 2993	8.8	2	6.24	6 51.36	2.8839	16 31 19.5	17.662	
392	SDM. —14 3059	8.2	2	6.22	7 17.81	2.9023	15 7 52.2	17.698	
393	SDM. —15 3015	[9.6]	2	6.22	10 10 4.37	+2.8962	15 56 22.9	—17.794	DM. $9^{M}.7$

No.		Magn.	No. Obs.	Epoch 1880+	α 1886.0	Prec.	δ 1886.0	Prec.	
					h m s	s	° ′ ″	″	
394	SDM. −15 3018	7.3?	2	6.27	10 10 45.71	+2.9014	−15 34 28.6	−17.819	
395	SDM. −16 3008	8.4	3	6.27	10 55.69	2.8944	16 12 29.5	17.826	
396	SDM. −15 3020	9.0	2	7.23	11 7.73	2.9051	15 18 2.9	17.831	
397	SDM. −14 3076	9.1	3	6.28	11 26.37	2.9076	15 7 32.3	17.846	[5^{M}.6
398	ε Sextantis		2	6.26	11 57.91	2.9926	7 30 0.1	17.867	p.m. Auwers. U.A.
399	SDM. −14 3086	[8.8]	2	6.22	13 34.78	2.9148	14 45 18.1	17.931	DM. 8^{M}.2
400	SDM. — 5 3013	8.2	2	6.24	14 55.57	3.0143	5 37 12.1	17.983	
401	SDM. −13 3091	8.9	5	6.65	14 58.27	2.9260	13 54 7.1	17.985	
402	SDM. −15 3030	8.5	2	6.25	15 5.05	2.9055	15 46 37.8	17.989	
403	SDM. −14 3093	7.8	4	6.28	15 19.23	2.9153	14 54 59.0	17.998	p.m. DM. 7^{M}.0
404		10.0	1	6.30	15 33.69	2.9227	14 16 41.5	18.008	
405	SDM. −13 3097	[7.5]	2	6.26	15 40.30	2.9342	13 12 47.1	18.012	U.A. 6^{M}.7
406	SDM. −14 3096	9.4	2	6.28	15 49.10	2.9230	14 17 4.3	18.018	
407	SDM. −14 3097	8.4	2	6.26	16 10.14	2.9197	14 37 35.7	18.031	
408	SDM. −13 3101	9.8	2	6.29	16 25.64	2.9280	13 53 34.3	18.041	
409	SDM. −12 3147	7.8	2	6.28	16 35.76	2.9396	12 50 5.6	18.047	p.m.? DM. 7^{M}.0
410	SDM. −12 3148	8.6	2	6.26	16 42.89	2.9368	13 6 2.4	18.052	
411	SDM. −12 3150	7.0	2	6.22	17 43.20	2.9414	12 48 0.0	18.090	
412	SDM. −12 3152	8.8	2	6.21	17 50.51	2.9392	13 1 7.6	18.095	
413	SDM. −13 3105	9.3	2	7.23	18 14.38	2.9349	13 27 41.2	18.110	
414	SDM. −12 3154	8.7	2	6.26	18 23.38	2.9428	12 44 38.2	18.115	
415	SDM. −12 3155	8.8	2	6.27	18 27.44	2.9391	13 5 27.1	18.118	
416	SDM. — 9 3067	8.5	2	6.27	19 16.62	2.9801	9 12 52.6	18.149	
417	SDM. −14 3116	8.7	2	6.26	19 49.12	2.9266	14 27 0.6	18.169	p.m.?
418	SDM. −12 3161	8.0	3	6.29	19 51.60	2.9504	12 11 3.7	18.170	
419	SDM. — 6 3141	6.5	2	6.30	20 2.38	3.0084	6 29 7.2	18.177	p.m. Auwers.
420	SDM. −12 3162	8.3	3	6.28	20 16.35	2.9468	12 33 18.0	18.185	DM. 7^{M}.3 [4^{M}.0
421	μ Hydrae		1	6.22	20 34.61	2.9084	16 15 16.8	18.197	p.m. Auwers. U.A.
422	SDM. −11 2880	8.8	2	6.28	20 46.24	2.9585	11 29 50.8	18.204	
423	SDM. −13 3119	9.2	3	6.27	21 17.58	2.9379	13 32 51.3	18.223	
424	SDM. −11 2884	[9.6]	2	6.22	23 24.52	2.9548	12 8 20.6	18.299	DM. 9^{M}.1
425	SDM. −11 2886	8.4	2	6.24	23 30.46	2.9578	11 51 8.8	18.303	DM. 7^{M}.8
426	β Sextantis		2	6.27	24 27.88	3.0717	0 3 10.6	18.337	U.A. 5^{M}.2
427	SDM. −11 2889	8.6	2	6.22	24 41.56	2.9620	11 32 57.0	18.345	
428	SDM. — 6 3171	9.3	1	6.26	25 13.18	3.0061	7 2 27.4	18.364	
429	SDM. — 6 3173	6.2	2	6.25	25 16.38	3.0059	7 3 11.8	18.365	
430	SDM. −12 3181	[7.5]	2	6.26	25 23.85	2.9486	13 0 15.4	18.370	U.A.
431	SDM. −11 2893	8.8	2	6.24	25 27.05	2.9666	11 10 32.6	18.372	DM. 8^{M}.0
432	SDM. −10 3076	8.0	2	6.22	26 22.24	2.9708	10 50 13.8	18.404	DM. 7^{M}.0
433	SDM. −10 3078	9.3	2	6.24	26 27.31	2.9678	11 8 55.9	18.407	
434	SDM. −10 3083	9.0	2	6.22	27 45.02	2.9781	10 12 31.3	18.451	
435	SDM. −10 3085	8.3	3	6.24	28 31.71	2.9743	10 41 5.9	18.478	
436	SDM. — 9 3101	7.5	2	6.22	28 37.92	2.9873	9 18 11.2	18.481	
437	SDM. −10 3086	8.7	2	6.25	28 46.97	2.9748	10 40 29.6	18.487	
438	SDM. −10 3089	8.6	2	6.24	28 57.27	2.9764	10 31 56.5	18.493	p.m.?
439	SDM. −11 2916	8.4	2	6.25	30 22.33	2.9705	11 18 56.2	18.540	DM. 7^{M}.8
440	SDM. — 9 3108	7.2	5	6.26	30 37.14	2.9829	9 59 33.0	18.548	[U.A. 6^{M}.2
441	SDM. −11 2918		2	6.24	30 51.82	2.9682	11 37 8.9	18.557	p.m. Argelander
442	SDM. −10 3094		2	6.22	31 32.99	2.9731	11 9 21.8	18.579	U.A. 6^{M}.8
443	SDM. — 8 2966	9.0	2	6.23	31 46.91	2.9934	8 56 30.7	18.587	
444	SDM. — 9 3113	9.0	2	6.22	33 14.30	2.9893	9 33 22.4	18.634	DM. 8^{M}.5
445	SDM. — 7 3083	7.5	3	6.25	33 47.41	3.0103	7 22 14.1	18.652	
446	SDM. — 9 3115	8.8	2	6.24	33 53.78	2.9909	9 26 0.2	18.655	
447	SDM. — 8 2975	8.8	2	6.24	34 7.24	2.9940	9 6 32.8	18.663	
448	SDM. — 8 2976	8.0	2	6.22	34 33.30	3.0001	8 27 0.8	18.677	
449	SDM. — 5 3124	8.0	2	6.25	36 9.13	3.0224	5 58 44.8	18.727	
450	SDM. — 7 3094	7.8	2	6.22	36 9.19	3.0099	7 27 36.3	18.727	
451	SDM. — 7 3097	7.9	2	6.23	36 44.73	3.0046	8 7 53.2	18.745	DM. 6^{M}.9
452	SDM. — 8 2997	9.0	3	6.23	40 28.52	2.9995	9 6 54.9	18.859	DM. 8^{M}.2
453	SDM. — 9 3147		2	6.22	44 1.25	3.0016	9 11 57.8	18.962	U.A. 6^{M}.4
454	SDM. — 6 3237	8.3	2	6.25	44 15.42	3.0201	6 52 42.0	18.969	
455	SDM. — 8 3018		4	6.25	10 44 31.97	+3.0095	— 8 17 39.5	−18.978	U.A. 6^{M}.0

No.		Magn.	No. Obs.	Epoch 1880+	α 1886.0	Prec.	δ 1886.0	Prec.
456	SDM. — 6 3252	7.7	2	6.21	10 47 5.56	+3.0269	— 6 12 40.0	—19.048
457	DM. + 4 2486		3	6.28	11 25 53.42	3.0870	+ 1 11 13.0	19.852
458			1	6.25	26 8.35	3.0869	1 12 48.9	19.835
459	DM. + 4 2497		3	6.29	28 36.87	3.0859	4 12 45.5	19.866
460			4	6.29	28 39.86	3.0859	4 13 10.6	19.866
461	DM. + 4 2499		2	6.26	29 56.11	3.0853	4 11 51.8	19.881
462			3	6.29	30 15.20	3.0838	3 45 7.7	19.885
463	DM. + 4 2502		2	6.26	30 31.21	3.0850	4 11 17.1	19.888
464	DM. + 3 2540		4	6.27	36 36.33	3.0806	3 25 23.9	19.919
465	DM. + 3 2541		4	6.27	11 36 55.59	+3.0806	+ 3 27 31.9	—19.952

MAXIMA AND MINIMA OF VARIABLE STARS, OBSERVED IN 1890.

BY PAUL S. YENDELL.

W Virginis.

From March 17 to July 18, thirty-five observations of this variable were obtained, from which were deduced six maxima and three minima.

The observations were much interrupted by bad weather, and the maxima, with the exception of the one occurring on April 23, were all obtained by the use of the mean light-curve; the exception, as well as all the times of minima, was deduced from the single curve.

The statement made on page 83 of Vol. IX of this Journal, that the star disappears at minimum in a telescope of $4\frac{1}{4}$-inch aperture, appears to have been an error, as it has been followed this year through three minima, with the same instrument, its light at no time falling below $10^M.0$.

The observed times are as follows:

Maxima	w	Minima	w
1890 March 19.8	2	1890 April 15.8	1
April 8.1	3	May 19.1	1
23.5	1	July 10.7	1
June 13.6	3		
July 1.9	2		
19.1	2		

R Ursae Majoris.

Nine observations show a maximum of this star to have taken place on June 14.5; the greatest observed light was estimated to be $7^M.3$.

S Ursae Majoris.

This star was observed on thirteen occasions between April 7 and June 15; a maximum of about $7^M.8$ took place on April 30, followed on May 18 by a secondary maximum of nearly the same brightness, after which the star's light rapidly fell away, being estimated at the last observation to be about $9^M.6$.

T Ursae Majoris.

Of this star only ten observations were obtained, from which a maximum of $7^M.5$ is inferred to have taken place on June 1.

χ Cygni.

χ Cygni was observed twenty-five times, from May 17 to Aug. 2; its maximum on June 17.1 was sharply marked, its light being equal to that of *ι Cygni*, or $4^M.2$, and conspicuous to the naked eye.

Dorchester, Mass., 1890 *Sept.* 20.

ON THE GREAT ECLIPSE AT ROME B.C. 187 JULY 17.

BY JOHN N. STOCKWELL.

The historian LIVY has given in book XXXVII, chap. 4, of his history, an account of an eclipse of the sun at Rome of which the following is a translation:

"At the time in which the consul set out to the war during the celebration of the Apollinarian games, on the fifth day before the ides of July, though the sky was serene, the light was obscured in the middle of the day, when the moon passed beneath the orb of the sun."

Such is the rather indefinite account of the event; but I have endeavored to supply, by calculation, the details which have been omitted by the historian. By employing the corrections to the lunar tables of HANSEN which are given in nos. 220-1, of this Journal, I find that the time of greatest eclipse at Rome was 7 11 mean local time, on the morning of July 17; at which time the magnitude of the eclipse was 10.9 digits on the sun's northern limb.

In this connection I may also mention that HANSEN's tables would give a somewhat larger eclipse at Rome, at 6 [illegible] in the morning.

Cleveland, 1890 *Sept.* 23.

THE VARIABLE STARS *T* AND *U MONOCEROTIS*, 1889–90.

BY EDWIN F. SAWYER.

T Monocerotis.

This star was under observation from 1889 November 14, to 1890 April 20; a very good series of observations, 60 in number, being obtained. From these the following epochs of maxima and minima have been deduced in Cambridge M.T., using the mean light-curve formed from the 1881–83 observations.

Observed Maxima	Observed Minima
d h m	d h m
1889 Nov. 28 19 26	1889 Nov. 20 15 58
Dec. 26 20 14	Dec. 18 11 49
1890 Jan. 21 10 9	1890 Jan. 14 11 8
Feb. 16 0 13	Feb. 9 18 54
Mar. 16 9 59	Mar. 9 7 58
Apr. 10 17 22	Apr. 2 21 47

Brighton, Mass., 1890 *September* 6.

U Monocerotis.

The observations on this star number 18, and extend from 1889 November 29, to 1890 April 20. From these observations the following times of maxima and minima have been determined:

		Light
Maximum =	1889 Dec. 28.0	Light = 23.8
	1890 Feb. 10.5	25.0
	Apr. 9.0	17.3
Minimum =	1890 Jan. 23.0	11.2
	Mar. 12.5	1.9

The interval between the first and second maximum = 44.5 days; and between the second and third maximum = 57.5 days. The interval between the two minima was 48.5 days. While the first was a bright minimum, the second was a very faint one.

FILAR-MICROMETER OBSERVATIONS OF COMET *c* 1890 (*DENNING*),

MADE WITH THE 13-INCH EQUATORIAL OF THE DUDLEY OBSERVATORY.

BY LEWIS BOSS.

1890 Albany M.T.	*	No. Comp.	☄ — * $\Delta\alpha$	☄ — * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
d h m s			m s	′ ″	h m s	° ′ ″		
Sept. 1 8 41 6	1	13 , 5	+6 0.72	+5 23.5	15 37 56.63	+24 18 9.2	9.601	0.600
4 9 18 27	2	15 , 5	−2 43.85	−2 23.9	15 40 34.95	+19 43 20.9	9.633	0.683
4 9 46 26	3	12 , 4	−2 12.02	+3 17.6	15 40 36.57	+19 11 33.7	9.650	0.705
18 7 54 33	4	38 , 11	−0 22.50	−1 0.0	15 53 7.29	+ 0 53 41.0	9.567	0.772

Mean Places for 1890.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	15 31 55.33	+0.58	+24 12 37.2	+8.5	Eq. comp. with Bonn VI +24°2891
2	15 43 18.18	+0.62	+19 45 37.1	+7.7	Bonn VI +19°3020
3	15 42 47.97	+0.62	+19 38 8.5	+7.6	Hist. Cel. (Lal. 28789), Bessel (Weisse 1020-1) and Eq. comp.
4	15 53 29.21	+0.58	+ 0 54 38.6	+2.4	Albany A.G.Z. 5328

NOTES.

Sept. 1. Observation very difficult. The comparison-star is Lalande 28479-80 and Weisse-Bessel 697. Compared with Bonn VI. +24°2891 was found: $\Delta\alpha = +43^s.25$; $\Delta\delta = -33''.3$. For 1890 we have:

	α	δ	
	h m s	° ′ ″	
H.C. 1794. April 25	15 31 55.52	+24 12 47.9	
H.C. 1794. June 14	56.65	45.0	2 threads
Weisse	55.52	39.3	1826.4
Eq. Comp.	15 31 55.33	+24 12 37.2	

In the uncertainty, the position obtained through equatorial comparison may, for the present, be regarded as safest. The separate threads in the Lalande observation of June 14 agree well.

Sept. 4. Lal. 28789—28771 was found to be: $\Delta\alpha = +48^s.26$; $\Delta\delta = +26''.7$. The position of * 3 derived in this manner was allowed to have weight in forming the adopted position. The observations of this night, as well as those of Sept. 18, are apparently entitled to fully twice the weight which may be assigned to the positions of this comet obtained by me on other occasions.

The above observations, together with the two reported in *Astronomical Journal*, no. 224, are all the observations of the comet of DENNING which I have found occasion to make.

LETTER FROM PROF. OUDEMANS TO THE EDITOR.

Perhaps this writing is wholly superfluous, in which case I beg pardon of my American fellow-astronomers: but I know by experience how easily routine work may lead one to forget an announced phenomenon on the day of its occurrence.

Looking over the list of occultations of stars by planets, and of their near approaches, published by Berberich in no. 2937 of the *Astronomische Nachrichten*, I was struck by the favorable chances of observing an occultation in the coming month of November.

For the American observatories, at least for the majority of them, the occultation of SD. −22° 5332 ($9^{\mathrm{M}}.4$) by *Mars*, on the 2d of November, will be of special interest.

The true conjunction is at $11^{\mathrm{h}}\,37^{\mathrm{m}}.6$ Mean Time at Berlin = $10^{\mathrm{h}}\,44^{\mathrm{m}}.0$ M.T. Greenwich = $5^{\mathrm{h}}\,35^{\mathrm{m}}.8$ Washington M.T. The difference of Decl. (Planet—Star) will be = +4″ geocentrically; the semi-diameter will be = 4″.6, the horizontal parallax of the planet = 7″.3 (the two last named quantities are from the English *Nautical Almanac*), and, according to Mr. Berberich's calculation, the maximum duration of the occultation will be $4^{\mathrm{m}}.3$.

The following table exhibits the circumstances for the American Observatories named in the list of the British *Nautical Almanac*, — the *American Ephemeris* not being at hand.

Observatory	L. M.T.	Time after Sunset	Alt.
Cambridge, Mass.,	5 59.5	+1 7.6	24
Quebec,	5 59.2	+1 17.0	20
McGill Obs'y, Montreal,	5 49.7	+1 4.4	21
Princeton,	5 46.4	+0 30.0	27
Albany,	5 49.0	+0 57.7	24
Washington, Naval Obser.,	5 35.8	+0 37.3	28
Georgetown College,	5 35.7	+0 37.3	28
Ann Arbor,	5 9.1	+0 17.0	25
Cincinnati,	5 6.3	+0 8.2	28
Chicago,	4 53.6	+0 0.6	25
[Washburn Obs'y, Wis.,	4 46.4	−0 4.1	24]
[Glasgow,	4 32.7	−0 25.2	28]
Cordoba,	6 27.2	+0 1.2	71
Rio Janeiro,	7 51.3	+1 37.0	73
[Santiago de Chile,	6 1.3	−0 27.8	74]
Buenos Aires,	6 50.5	+0 19.6	65

The lines in square brackets are for the observatories, where the conjunction happens before sunset.

If the weather is a little favorable, the observations of this occultation will be highly interesting.

J. A. C. Oudemans.

Utrecht, 1890 *September* 23.

COMET *d* 1890.

This, which is evidently a return of the periodic comet of d'Arrest, was discovered by Barnard, at the Lick Observatory, on the night of October 6. He telegraphed the position: —

Oct. 6, Greenw. M.T. $\alpha = 19^{\mathrm{h}}\,13^{\mathrm{m}}\,31^{\mathrm{s}}$, $\delta = -26°\,7'\,30''$. Daily motion, $+3^{\mathrm{m}}\,28^{\mathrm{s}}$ in α, and 0° 26′ southward.

This place agreed, within less than 10^{s}, and 1½′, with Leveau's ephemeris, and the direction of motion was essentially the same. He reports the comet as quite faint.

EPHEMERIS OF THE COMET OF D'ARREST.

By Rev. G. M. Searle.

The observation by Barnard of D'Arrest's comet indicating a correction of $d\lambda = -9'\,14''$, $d\beta = -1'\,6''$, to Leveau's elements for epoch Feb. 25.0, it seemed at first probable that a change in the mean anomaly only would be needed to represent the observation sufficiently well.

But it was found that a change in some other element would also be required, and ☊ was selected as the one most likely to vary, and most efficient in its effect on the latitude. The observation gave

$$dM = -1'\,21'' \;, \quad d\Omega = -11'\,11''$$

for a provisional correction of the elements.

From these we have the ephemeris, for Greenwich midnight, mean equinox 1890.0,

Date		α		δ	log Δ
Oct. 19	20	5	33	−27 53.1	9.9682
23		21	51	28 3.8	.9821
27		37	59	28 1.5	9.9961
31	20	53	51	27 55.8	0.0102
Nov. 4	21	9	22	27 38.1	.0247
8		24	31	27 15.0	.0396
12		39	15	26 40.3	.0547
16	21	53	32	−26 1.4	0.0701

computed simply from the coordinate formulas for 1890.0

$$x = [9.994984]\; r \sin(e + 50°\;14'\;11'')$$
$$y = [9.993089]\; r \sin(e + 321°\;4'\;15'')$$
$$z = [9.366812]\; r \sin(e + 280°\;52'\;31'')$$

This ephemeris differs by about $-0^{\mathrm{m}}.3$ and $-3'$ from that of Leveau. Either will probably do very well to find the comet for a considerable time.

FILAR-MICROMETER OBSERVATIONS OF COMET *d* 1890 (*BARNARD. Oct. 6*),

MADE WITH THE 12-INCH EQUATORIAL OF THE LICK OBSERVATORY,

BY E. E. BARNARD.

1890 Mt. Hamilton M.T.	✱	No. Comp.	☄ — ✱		☄'s apparent		log $p\Delta$	
			$\Delta\alpha$	$\Delta\delta$	α	δ	for α	for δ
d h m s			m s	′ ″	h m s	° ′ ″		
Oct. 6 9 23 40	1	5 , 6	+0 17.37*	−2 7.0	19 13 30.88	−26 7 30.5	9.590	0.837
7 7 34 49	2	16 , 6	+2 15.63	+3 22.9	19 17 15.03	−26 18 51.7	9.322	0.886
8 6 55 58	3	12 , 1	+1 14.20	+2 1.0	19 21 11.48	−26 30 7.6	9.017	0.895

Mean Places for 1890.0 of Comparison-Stars.

✱	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	19 13 11.85	+1.66	−26 5 22.7	−0.8	Gould G.C. 26158
2	19 14 57.74	+1.66	−26 22 13.6	−1.0	do. 26496
3	19 19 55.61	+1.67	−26 32 7.7	−0.9	do. 26615

This comet was discovered Oct. 6d 8h 30m Mt. Hamilton M.T., with the 12-inch equatorial, just after observing **Denning**'s comet for position. It was faint, round, very gradually somewhat brighter in the middle, with no nucleus or tail. It is large, 2½′ or 3′ in diameter, and resembles a periodic comet in its light.

Mt. Hamilton, 1890 *Oct.* 8.

* Oct. 6, the $\Delta\alpha$ was measured with the micrometer = +229″.5.

TWO HUNDRED NINETY-NINTH ASTEROID.

A planet of the 13th magnitude was discovered by **Palisa**, at Vienna, Oct. 6. in the position

1890 Oct. 6d.4883 Greenw. M.T. $\alpha = 2^h\ 16^m\ 20^s.8$. $\delta = +15°\ 18'\ 25''$. Daily motion, -40^s in α, and 2′ southward.

NEW ASTRONOMICAL WORK.

Astronomical Papers, prepared for the use of the American Ephemeris and Nautical Almanac. Vol. II. part V. — *Discussion of Observations of the Transits of Venus*, 1761 and 1769, *by* **Simon Newcomb**.

The largely superior values for the solar parallax, deduced in more recent years, have much impaired the confidence previously placed in the determinations from the transits of *Venus* in the last century. Not merely has this mode of determination been found less accurate than sundry other methods; but the trustworthiness of many of the observations themselves has been seriously discredited.

The investigations of **Powalky**, twenty years ago, showed nevertheless, that a repetition of **Encke**'s computations, after correcting some of the fundamental data, would give results far more accordant with the later values, obtained in other ways. Prof. **Newcomb** has now undertaken the whole problem anew, — applying a searching criticism to all the observations of both transits, and using improved values for the longitudes of the places of observation. His personal examination of Father **Hell**'s manuscript record of the observations made in 1769 at Wardoe had already resulted in vindicating the published results, against the rude impeachments which had been brought against them; and these especially important data have consequently been used with a large weight.

The final values, deduced from the two transits, are 8″.79 ± 0″.05 for the parallax, and +32″.4 for the correction to **LeVerrier**'s longitude of the node of *Venus*, for the mean date. The difference between this result and that of **Encke** (8″.58) arises, chiefly, (1) from the introduction of a correction for imperfection of telescopes and other obstacles to distinct vision of the thread of light, and (2) from the inclusion of numerous observations omitted by **Encke**. The increase in the apparent probable error of the result is due to this mode of treatment, which of course makes the observations seem more discordant.

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Letter from Prof. Oudemans to the Editor.
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Ephemeris of the Comet of D'Arrest, by Rev. G. M. Searle.
Filar-Micrometer Observations of Comet *d* 1890, by Prof. E. E. Barnard.
Two Hundred Ninety-Ninth Asteroid.
New Astronomical Work.

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OBSERVATIONS OF THE SATELLITES OF *MARS*,

By JAMES E. KEELER, Astronomer of the Lick Observatory.

During the past opposition of *Mars* I made a few micrometer measures of the satellites with the thirty-six inch equatorial, at the request of Professor Holden. Notwithstanding the very unfavorable position of *Mars*, the satellites were easily visible on nearly every evening,* but as the observations interfered with other uses of the telescope, only a sufficient number of measurements were made to give an approximate correction to the ephemerides. Other measures of the satellites have doubtless been made elsewhere.

The brightness of the planet was reduced by a thin slip of lightly smoked glass, nearly in contact with the micrometer-threads, to which its sides were made parallel, in order not to embarrass the judgement by the presence of oblique lines. The systematic errors, arising from the bisection by estimate of so large a disc as that of *Mars*, are partially eliminated by the observation of a satellite on both sides of the planet. A power of 520 was always used.

The position-angles and distances are corrected for phase of *Mars*, and therefore refer to the center of the planet.

June 1, 1890.

Night calm; seeing 3 on scale of 5. Clouds came up shortly after 13^h and interfered with observations.

Observations of *Deimos*.

Pacific Time	*p*	Pacific Time	*s*
h m s	°	h m s	″
12 58 40	307.6	13 7 50	67.2
13 2 50	307.9	13 10 10	67.1
13 4 0	307.9	13 11 50	66.8

June 5, 1890.

Considerable wind, causing the telescope to vibrate slightly. Seeing 3. *Deimos* was not seen.

Observations of *Phobos*.

Pacific Time	*p*	Pacific Time	*s*
h m s	°	h m s	″
11 51 30	298.2	12 7 20	21.2
11 56 0	297.8	12 10 0	21.7
11 58 10	298.8	12 11 50	22.4
12 0 10	298.2	12 13 20	22.4
12 3 30	299.2	12 15 50	22.9

Observations of *Phobos*. — *Continued*.

Pacific Time	*s*
h m s	″
12 21 40	23.9
12 24 20	24.6
12 25 30	24.8
12 26 40	24.6
12 27 40	25.2

June 6, 1890.

Night calm; seeing 3.

Observations of *Deimos*.

Pacific Time	*p*	Pacific Time	*s*
h m s	°	h m s	″
9 19 30	125.5	9 36 40	65.9
9 24 50	126.1	9 38 40	65.3
9 27 50	126.2	9 41 0	65.2
9 29 10	126.5	9 42 20	65.4
9 30 30	126.0	9 46 10	66.0
(Reversed the Telescope.			
10 49 40	129.3	11 8 10	65.9
10 52 50	129.9	11 9 30	66.1
10 54 50	130.0	11 10 40	66.2
10 58 30	130.2	11 12 40	65.6
11 2 0	130.2	11 14 10	65.9

Observations of *Phobos*.

Pacific Time	*s*	Pacific Time	*p*
h m s	″	h m s	°
11 18 0	24.2	11 28 50	303.5
11 20 0	24.0	11 31 10	304.8
11 22 10	24.1	11 32 30	304.7
11 24 10	24.9	11 35 0	304.9
11 25 50	24.9	11 36 20	305.4

---

* They were sometimes seen on public nights by visitors who were unaware of their existence. On such occasions no occulting bar was used.

Observations of *Phobos*. — *Continued.*

Pacific Time	*s*
h m s	″
11 40 20	26.4
11 41 30	26.7
11 42 40	26.8
11 46 40	27.1
11 48 30	27.1

June 12, 1890.

Night calm; seeing bad, = about 2.

Observations of *Phobos*.

Pacific Time	*p*
h m s	°
10 25 40	140.2
10 27 10	141.8
10 33 10	143.4
10 38 0	143.8
10 39 50	141.7

June 26, 1890.

Night calm; thin haze and moonlight; seeing about 3. Measures made after reappearance of *Phobos* from eclipse.

Observations of *Phobos*.

Pacific Time	*p*	Pacific Time	*s*
h m s	°	h m s	″
9 56 40	128.0	10 8 10	24.1
9 59 0	128.5	10 9 30	24.2
10 1 20	129.1	10 18 40	24.7
10 2 30	128.8	10 56 40	19.3
10 5 10	128.8	11 0 0	18.8

July 18, 1890.

Seeing 3. After the reappearance of *Phobos* from eclipse two measures of distance were made.

Observations of *Phobos*.

Pacific Time	*s*
h m s	″
9 39 0	17.3
9 41 10	18.3

Observations of Eclipses of the Satellites.

In an account of observations of the satellites of *Mars* in 1888*, I pointed out the probability that the eclipses of the satellites could be observed with the great telescope in favorable oppositions. Experience has shown that this is quite possible; but partly on account of reasons already given, and partly on account of the very low altitude of *Mars*, which restricted the observations to a small hour-angle, only a very few eclipses were observed during the opposition of the past summer. There is no doubt that at a favorable opposition, with *Mars* at a high altitude, a long series of eclipses can be observed, and the positions of the satellites determined with much greater precision than that which is attainable by the aid of micrometer measurements alone. For this purpose an ephemeris like that of Mr. Marth, in which the eclipses are predicted, is almost indispensable.

In observing the eclipses of the satellites at the Lick Observatory, the planet was hidden behind a thickly smoked slip of glass, which just allowed the outline of the disc to be seen. The eyepiece was turned so that this occulting bar was perpendicular to the line joining the center of *Mars* and the estimated place of reappearance of the satellite, and rocked gently back and forth by the screw of its slide in order that any small point of light should more readily catch the eye. The time was noted at each suspected appearance, usually by an assistant.

The eclipses before opposition could not be seen on account of cloudy weather. Such observations as were made after opposition (including failures) are given below.

June 12, 1890.

Looked for eclipse of *Deimos*, which according to the ephemeris should occur at about 10^h 20^m, but could see nothing of the satellite. Definition bad, = 2. *Deimos* first seen at 12^h, then about 1 diameter from limb of *Mars*. It was very dim.

June 26, 1890.

Night calm; seeing 3 on scale of 5. The sky is covered with thin haze, and the moon is past first quarter, hence the field is full of milky light. *Phobos* was first seen at 9^h 20^m 26^s Pacific Time, after several suspected reappearances had been noted, and was rather dim, but two minutes later could be seen readily. The time is probably not much in error. Reappearance of *Deimos* looked for, but not seen.

July 1, 1890.

An attempt was made to observe the eclipse of *Deimos*, but nothing could be seen of the satellite at 9^h 15^m. The full moon shining on the object-glass filled the field with light. *Phobos* was not seen.

July 2, 1890.

Night calm and clear; seeing 3 to 4. *Phobos* appeared quite suddenly at 10^h 41^m 21^s Pacific Standard Time, and this observation is believed to be correct to within a few seconds.

---

* See *Astronomical Journal*, no. 178.

July 11, 1890.

Seeing very bad, = 1. Reappearance of *Phobos* suspected at $9^h\ 6^m\ 58^s$; certainly seen at $9^h\ 12^m\ 8^s$; it was very dim, and could not be held steadily. Observation considered worthless.

July 18, 1890.

Seeing = 3. *Phobos* reappeared suddenly at $9^h\ 32^m\ 34^s$ Pacific Time, and the observation appeared to be good.

NOTE ON THE ACTION OF *JUPITER* IN 1886 UPON COMET *d* 1889.

BY CHARLES LANE POOR.

[Fellow of the Johns Hopkins University.]

In Mr. CHANDLER's paper on the action of *Jupiter* upon Comet *d* 1889, found in the *Astronomical Journal*, no. 205, it is stated that the particular numerical results, there given, are to be regarded merely as a rude sketch, in the nature of a reconnoissance survey of the problem. I have, with Mr. CHANDLER's assent, carried his work a few steps farther; have made a second approximation to the numerical solution of the problem.

The elements used by Mr. CHANDLER were first corrected by the method of varying the geocentric distances — the last observation used being that of February 15, made at Princeton. The following elements were derived and used for the subsequent work.

$$T = 1889 \text{ Sept. } 30.26274 \text{ Gr. M.T.}$$

$$\left.\begin{array}{rcrrr} \pi & = & 1^\circ & 33' & 8''.70 \\ \Omega & = & 17 & 58 & 51\ .96 \\ i & = & 6 & 4 & 7\ .95 \end{array}\right\} 1890.0$$

$$\log e = 9.6724290$$
$$\log a = 0.5659228$$
$$\log \mu = 2.7011224$$

The perturbations by *Jupiter* were then computed from September 1888 to the time of appulse in October 1886. An interval of forty days was used until March 1887, when it was reduced to ten days, then to four, and finally to a single day. This gave for the elements of 1886 Oct. 17.0, the following,

$$L = 211^\circ\ \ 1'\ 20''.8$$

$$\left.\begin{array}{rcrrr} \pi & = & 2 & 36 & 52\ .7 \\ \Omega & = & 19 & 0 & 11\ .4 \\ \varphi & = & 31 & 47 & 5\ .4 \end{array}\right\} 1890.0$$

$$i = 7\ \ 23\ \ 14\ .9$$
$$\log \mu = 2.7198412$$
$$\log a = 0.5531135$$

Following the method given by LAPLACE, I at this point transferred the center of motion from the sun to *Jupiter*, and found the following hyperbolic orbit in which the comet moved about *Jupiter* between 1886 Mar. 29.0 and Oct. 17.0. The elements of the hyperbola are those of Oct. 17.0.

$$\left.\begin{array}{rcrrr} \pi & = & 297^\circ & 40' & 0''.4 \\ \Omega & = & 241 & 28 & 41\ .2 \\ i & = & 35 & 33 & 29\ .0 \end{array}\right\} 1890.0$$

$$\log a = n8.9542352$$
$$\log e = 0.0436218$$
$$T = 1886 \text{ July } 4.47444$$

I then computed the perturbations due to the action of the sun on the comet, while the latter was traversing the above hyperbolic orbit. The method of rectangular coordinates was used. At first, a ten-day interval was found satisfactory; but as the comet approached its perijove, this interval had to be decreased to two days, and finally to a single day. After the comet had well passed its perijove the interval was first increased to two days, and finally to ten days. Thus were found the rectangular coordinates and their differential coefficients for the comet on March 29.0, the day on which I referred the comet's motion back again to the sun as a center. The orbit thus deduced is,

$$\left.\begin{array}{rcrrr} \pi & = & 221^\circ & 29' & 42''.00 \\ \Omega & = & 182 & 54 & 14\ .87 \\ i & = & 9 & 28 & 15\ .10 \end{array}\right\} 1890.0$$

$$\log e = 9.6571959$$
$$\log a = 0.9822130$$
$$\log \mu = 2.0766871$$
$$T = 1887 \text{ June } 6.4829 \text{ Gr. M.T.}$$
$$\text{Period} = 29.7386 \text{ years.}$$

Computing the perturbations by *Jupiter* from March 29.0 to February 8.0, and using eight-day intervals, I find for the elements of the comet's path about the sun on 1886 February 8.0,

$$\left.\begin{array}{rcrrr} \pi & = & 221 & 10 & 56''.6 \\ \Omega & = & 183 & 1 & 23\ .4 \\ i & = & 9 & 4 & 26\ .1 \end{array}\right\} 1886.0$$

$$\varphi = 25\ \ 34\ \ 16\ .6$$

$$\log \mu = 2.0999981$$
$$\log a = 0.9666721$$
$$T = 1887 \text{ June } 8.61633 \text{ Gr. M.T.}$$

This result is to be regarded merely as a good approximation, and is still liable to some slight changes in my own work.

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ON THE REDISCOVERY OF D'ARREST'S COMET,

By E. E. BARNARD.

I began a careful search for D'Arrest's periodic comet on April 14 of this year, and kept it up on every favorable occasion until Sept. 4, after which date the search was given up as hopeless, as the comet was decreasing in light, and was getting into a poor position for finding. From that time the comet dropped entirely from my memory.

On October 6, while sweeping with the 12-inch near the southern horizon, I ran upon a very faint diffused nebulosity, some 2′ or 3′ in diameter, which was at once recognized as a comet. Its position and direction of motion were determined, and the discovery was telegraphically announced as that of a new comet.

From the first three observations, on successive nights, Mr. Schaeberle computed a preliminary orbit, and upon comparing this with previous orbits, it was at once seen that the object must be the long looked for D'Arrest's comet. A comparison with M. Leveau's ephemeris in *Astr. Nachr.* 2959 proved the truth of this beyond question.

The discovery was entirely in the line of original search, and without any recollection of the position, or even of the existence of D'Arrest's comet.

On the first few nights, while the observations were being made with the micrometer, the comet was extremely faint and diffused; but since that time it has steadily increased in brightness, or rather it has apparently increased in density, and, before the moon interfered, it was seen on several nights in the $3\frac{1}{4}$-inch finder of the 12-inch.

At these last observations the theoretical light of the comet was 0.6. From its distinctness then, I think it could be observed when only one-tenth as bright. It should therefore be seen until well into next year. Its light on December 18 (0.15) will be the limit of minimum visibility at any previous return. Since April 22 of this year, the light, theoretically, has all the time been much above this limit, and in the mean time the comet has been in an extremely favorable position for discovery. The maximum brightness, 1.03, was attained about the last of August. From the middle of April until October, the light must have been remarkably low for the comet to escape detection with the most powerful telescopes in the world.

According to M. Leveau, the theoretical light, at previous returns, while the comet was under observation, ranged in

1851 from 1.50 to 0.60
1857 " 0.23 " 0.16
1870 " 0.89 " 0.15
1877 " 0.20 " 0.15

In 1883 the maximum light, while favorably placed for observing, was 0.09, and the most careful search failed to find the comet.

At the present apparition the light has been above 0.15 since April 22, and the comet has been most excellently placed for observing. The search for it at this return has been the most thorough and exhaustive perhaps that was ever made for any comet, and it seems to have been abandoned as hopeless only after the comet had passed its greatest brightness and most favorable position.

These considerations lead us to the important question of the condition of the comet's light during the past six months. Especially is this the case when we find that during all this time the comet must have been close to the ephemeris-place; indeed, it must have been in any ordinary low-power field when the telescope was set to the ephemeris-position, for the observations give a correction (Oct. 15) of only $-0^{m}.5$ and $-3'$ to M. Leveau's ephemeris.

The following are the dates upon which the comet was sought for, with the 12-inch. Though a record was kept of the extent of the sweeps, etc., it is not necessary to print such here because we now know that the comet must have followed the ephemeris closely.

1890 April 14, air unsteady, but transparent. April 24, covered the place well. April 26, seeing 1. May 8, seeing poor. May 11, sky milky. May 12, seeing poor. May 14, sky poor. May 15, seeing rather poor. May 17, seeing poor. May 18, seeing fair. May 20, seeing fair. May 25, seeing good. June 5, seeing fair, place well located by DM. stars, thorough and careful search. "The comet can not be near its ephemeris-place, or it must be excessively faint." light 0.4. June 8, good. June 16, good. June 17, searched with 36-inch, three new nebulas found near the comet's place, seeing not very good. June 18, the three nebulas seen again with 36-inch in the places of last night. July 3, fair. July 4, good. An object, supposed to be D'Arrest's comet, found

α (apparent) $16^{h}\ 5^{m}\ 21^{s}.70$
δ (apparent) $+10^{\circ}\ 19'\ 36''.7$

Very faint, between a $7^{M}.5$ star and a 10^{M} star. As there was not sufficient time before moon-rise to detect motion, the object from its closeness to the ephemeris-place was assumed to be the comet, and its position was determined with the micrometer, and a cipher-telegram made out, containing the position ready to send off the following night as soon as the comet was verified, but —— July 5, the object of last night found to be a new nebula. July 6, seeing fair, searched three hours for the comet, with magnifying powers of 80 and 150, all over and about the place; at this time the light of the comet was 0.7. July 13, seeing = 5. July 16, searched for two hours, seeing good. August 4, searched for two hours, seeing good; light = 0.96. Sept. 3, seeing good. Sept. 4, seeing good; light = 1.03.

After this prolonged search, often extending over 5° or 6° on each side of the ephemeris-place, and frequently occupying several hours' time, it appeared justifiable to abandon the comet to its fate, especially as the theoretical light was now diminishing.

While looking for the comet, quite a number of new nebulas were discovered. These are retained for publication in a list of new nebulas discovered here.

The return of this comet in 1870 was almost exactly under the same conditions as that of the present year. Indeed, the paths were so nearly alike, that an ephemeris of the comet for 1870 would have served as a rough finding ephemeris for this year. When found by me, Oct. 6, the comet was at $9^h\ 21^m$ in

$$\alpha = 19^h\ 13^m.5, \qquad \delta = -26°\ 7'.$$

When observed by Schmidt at Athens, 1870 Oct. 15, at $7^h\ 3^m$, the position of the comet was

$$\alpha = 19^h\ 12^m.3, \qquad \delta = -26°\ 11'.$$

It was Winnecke, however, who discovered the comet at its appearance in 1870, on August 31.

At the present return the comet must have very recently passed quite close to *Mars*.

Following are the last two positions of the comet before the moon interfered.

1890 Mt. Hamilton M.T.	*	No. Comp.	☍—* Δα	☍—* Δδ	☍'s apparent α	☍'s apparent δ	log pΔ for α	log pΔ for δ
d h m s			m s	′ ″	h m s	° ′ ″		
Oct. 16 7 21 24	11	18 , 7	+1 36.24	−7 8.4	19 54 2.24	−27 39 39.0	9.215	0.890
17 8 5 36	12	18 , 6	+0 21.40	+5 10.7	19 58 6.20	−27 45 15.9	9.403	0.881

Mean Places for 1890 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
11	19 52 24.30	+1.70	−27 32 30.4	−0.2	Gould G.C. 27340
12	19 57 43.10	+1.70	−27 50 26.3	−0.3	Comp. with Gould G.C. 27430

Up to the time the moon came into the evening sky, the comet was observed on the following dates with the 12-inch: October 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16 and 17. Some of the comparison-stars have not yet been identified, so the observations on the other dates are withheld except those of Oct. 6, 7 and 8, which have been already sent to the *Journal*.

Mt. Hamilton, 1890 *Oct.* 24.

EPHEMERIS OF VARIABLES OF THE *ALGOL*-TYPE.

Approximate Greenwich M.T., 1890.

In the following ephemeris the star *S Antliae* is not included, for the reason stated on another page of this number, where a separate ephemeris for it will be found covering the coming season of its visibility.

November	d h	November	d h	December	d h	December	d h	December	d h
R Can. Maj.	12 11	*Y* Cygni	22 16	δ Librae	4 16	λ Tauri	13 9	*R* Can. Maj.	23 8
U Cephei	12 12	*R* Can. Maj.	22 16	Algol	4 21	Algol	13 11	*R* Can. Maj.	24 12
R Can. Maj.	13 14	λ Tauri	23 14	λ Tauri	5 14	*Y* Cygni	13 15	*U* Cephei	24 21
Y Cygni	13 16	*Y* Cygni	25 16	*U* Coronae	5 17	*R* Can. Maj.	15 9	λ Tauri	25 5
R Can. Maj.	14 17	*S* Cancri	27 6	*S* Cancri	6 18	*S* Cancri	16 5	*Y* Cygni	25 15
Algol	14 19	*U* Cephei	27 11	*U* Cephei	7 10	*R* Can. Maj.	16 13	*R* Can. Maj.	25 15
λ Tauri	15 17	*R* Can. Maj.	28 9	*R* Can. Maj.	7 11	*Y* Cygni	16 15	δ Librae	25 14
Y Cygni	16 16	*Y* Cygni	28 16	*Y* Cygni	7 16	λ Tauri	17 8	*S* Cancri	25 17
U Cephei	17 11	*U* Coronae	28 20	Algol	7 18	*U* Cephei	17 10	*U* Coronae	26 10
Algol	17 16	*R* Can. Maj.	29 12	*R* Can. Maj.	8 14	*R* Can. Maj.	17 16	*U* Cephei	27 9
S Cancri	17 19	*R* Can. Maj.	30 15	λ Tauri	9 10	δ Librae	18 15	Algol	27 19
U Coronae	18 11			*R* Can. Maj.	9 17	*R* Can. Maj.	18 19	*Y* Cygni	28 15
λ Tauri	19 15	December		Algol	10 15	*U* Coronae	19 13	λ Tauri	29 4
Y Cygni	19 16	λ Tauri	1 12	*Y* Cygni	10 15	*Y* Cygni	19 15	*U* Cephei	29 21
R Can. Maj.	20 10	*Y* Cygni	1 16	*R* Can. Maj.	10 20	*U* Cephei	19 21	Algol	30 16
Algol	20 13	*R* Can. Maj.	1 18	δ Librae	11 16	λ Tauri	21 6	*R* Can. Maj.	31 7
R Can. Maj.	21 13	*U* Cephei	2 10	*U* Cephei	12 10	*U* Cephei	22 9	*Y* Cygni	31 15
U Cephei	22 11	*Y* Cygni	4 16	*U* Coronae	12 15	*Y* Cygni	22 15		

EPHEMERIS OF *S ANTLIAE*,

BY S. C. CHANDLER.

In the synchronistic ephemeris of the variables of the *Algol*-type on a preceding page, *S Antliae* was not included, because the minima occur so frequently that the ephemeris in that form would require an inordinate space. It is therefore given here separately for the whole season 1890–1891, during which the star is visible, in a form similar to that used by me previously for other stars. It is based on the elements given in the supplement to the variable star catalogue (*A.J.*, IX, pp. 186, 7; see also p. 190). The exact Greenwich mean time of any minimum, by those elements, for any date in the table, is found simply by applying to the time in the right-hand column, opposite the date, the correction at the foot of the column of dates. The numbers at the head of each column indicate the numbering of the epochs, being the numbers of the first and last minima in the column below. Thus, the exact computed time, by the elements, of E 3418 is 1891 Apr. 26^d 13^h 48^m.2 —50^m.4 = 1891 Apr. 26^d 12^h 57^m.8.

EPHEMERIS OF *S Antliae*.

2988 to 3024	3025 to 3061	3062 to 3098	3099 to 3135	3136 to 3172	3173 to 3209	3210 to 3246	3247 to 3283	3284 to 3320	3321 to 3357	3358 to 3394	3395 to 3431	Greenwich M.T.
1890	1890	1891	1891	1891	1891	1891	1891	1891	1891	1891	1891	h m
Dec. 8	Dec. 20	Jan. 1	Jan. 13	Jan. 25	Feb. 6	Feb. 18	Mar. 2	Mar. 14	Mar. 26	Apr. 7	Apr. 19	2 51.8
8	20	1	13	25	6	18	2	14	26	7	19	10 38.6
8	20	1	13	25	6	18	2	14	26	7	19	18 25.4
9	21	2	14	26	7	19	3	15	27	8	20	2 12.2
9	21	2	14	26	7	19	3	15	27	8	20	9 59.0
9	21	2	14	26	7	19	3	15	27	8	20	17 45.8
10	22	3	15	27	8	20	4	16	28	9	21	1 32.6
10	22	3	15	27	8	20	4	16	28	9	21	9 19.4
10	22	3	15	27	8	20	4	16	28	9	21	17 6.2
11	23	4	16	28	9	21	5	17	29	10	22	0 53.0
11	23	4	16	28	9	21	5	17	29	10	22	8 39.8
11	23	4	16	28	9	21	5	17	29	10	22	16 26.6
12	24	5	17	29	10	22	6	18	30	11	23	0 13.4
12	24	5	17	29	10	22	6	18	30	11	23	8 0.2
12	24	5	17	29	10	22	6	18	30	11	23	15 47.0
12	24	5	17	29	10	22	6	18	30	11	23	23 33.8
13	25	6	18	30	11	23	7	19	31	12	24	7 20.6
13	25	6	18	30	11	23	7	19	31	12	24	15 7.4
13	25	6	18	30	11	23	7	19	31	12	24	22 51.2
14	26	7	19	31	12	24	8	20	Apr. 1	13	25	6 41.0
14	26	7	19	31	12	24	8	20	1	13	25	14 27.8
14	26	7	19	31	12	24	8	20	1	13	25	22 14.6
15	27	8	20	Feb. 1	13	25	9	21	2	14	26	6 1.4
15	27	8	20	1	13	25	9	21	2	14	26	13 48.2
15	27	8	20	1	13	25	9	21	2	14	26	21 35.0
16	28	9	21	2	14	26	10	22	3	15	27	5 21.8
16	28	9	21	2	14	26	10	22	3	15	27	13 8.6
16	28	9	21	2	14	26	10	22	3	15	27	20 55.4
17	29	10	22	3	15	27	11	23	4	16	28	4 42.2
17	29	10	22	3	15	27	11	23	4	16	28	12 29.0
17	29	10	22	3	15	27	11	23	4	16	28	20 15.8
18	30	11	23	4	16	28	12	24	5	17	29	4 2.6
18	30	11	23	4	16	28	12	24	5	17	29	11 49.4
18	30	11	23	4	16	28	12	24	5	17	29	19 36.2
19	31	12	24	5	17	Mar. 1	13	25	6	18	30	3 23.0
19	31	12	24	5	17	1	13	25	6	18	30	11 9.8
19	31	12	24	5	17	1	13	25	6	18	30	18 56.6
m	m	m	m	m	m	m	m	m	m	m	m	
+42.0	+33.6	+25.2	+16.8	+8.4	0.0	—8.4	—16.8	—25.2	—33.6	—42.0	—50.4	

It may also be observed that 1200 periods are exactly 389 solar days, a property that enables us to make use of the table for the precise comparison of observations in other years with the elements. Thus, subtracting 1200 periods and 24 days from the example above, we have the computed time of E 2218, 1890 Apr. 2d 12h 57m.8. Now we have an observation of this minimum on p. 190, Vol. IX.

	d h m
Observed Cambridge M.T.,	1890 April 2 8 16.5
Long., Greenw.-Cambr.,	+4 44.5
Light equation,	+ 5.0
Observed time, corrected,	1890 April 2 13 6.0
Computed time, as above,	1890 April 2 12 57.8
O—C,	+8.2

precisely as given in the place cited. By adding or subtracting appropriate multiples of 1200 periods and 24 days (23 days in leap years) observations in any year may be similarly compared.

FILAR-MICROMETER OBSERVATIONS OF COMET *c* 1890 (*DENNING*),

MADE WITH THE 12-INCH EQUATORIAL OF THE LICK OBSERVATORY.

By E. E. BARNARD.

1890 Mt. Hamilton M.T.	*	No. Comp.	☌—* Δα	☌—* Δδ	☌'s apparent α	☌'s apparent δ	logpΔ [illegible]	logpΔ [illegible]
h m s			m s	′ ″	h m s	° ′ ″		
July 25 13 21 55	1	12 , 6	+1 41.11	+ 1 3.2	15 13 46.8	+76 7	0.289	0.299
25 15 13 58	2	6	—0 35.97	. . . . .	15 13 49.39	. . . .	0.207	. . .
25 15 37 29	2	4	. . . . . .	+ 9 20.0	. . . .	+76 2 14.4	. . .	0.756
26 13 37 29	3	4	. . . . . .	— 7 39.1	. . . .	+75 7 43.8	. . .	0.122
26 13 44 18	3	8	—6 29.65	. . . . .	15 13 17.23	. . . .	9.894	. . .
27 13 54 20	4	12	+1 18.15	. . . . .	15 13 57.68	. . . .	0.217	. . .
27 14 23 52	4	5	. . . . . .	—11 4.5	. . . .	+74 6 27.0	. . .	0.620
27 13 57 23	5	8	+1 1.52	. . . . .	15 13 57.96	. . . .	0.269	. . .
27 14 51 20	5	7	. . . . . .	— 6 4.1	. . . .	+74 5 14.9	. . .	0.679
Aug. 3 9 30 40	6	12 , 5	—1 25.05	+ 1 38.8	15 15 51.71	+66 30 37.4	9.713	n0.365
6 9 23 24	7	*4 , 6	—0 17.16	— 4 29.1	15 17 36.01	+62 47 53.4	9.876	0.279
8 10 1 18	8	3	. . . . . .	+ 4 58.1	. . . .	+60 9 56.4	. . .	9.740
8 10 10 52	8	* 3	—0 5.25	. . . . .	15 18 51.31	. . . .	9.914	. . .
10 10 39 55	9	3	. . . . . .	— 7 14.6	. . . .	+57 11 6.7	. . .	9.921
10 10 56 59	9	10	+0 14.44	. . . . .	15 20 14.15	. . . .	9.925	. . .
12 9 32 33	10	*3 , 6	+0 0.44	+ 5 43.3	15 21 36.68	+51 43 0.1	9.819	n9.176
14 10 23 41	11	18 , 6	+0 20.68	+ 1 10.2	15 23 8.3	+51 42.6	9.846	0.118
15 9 55 22	12	*3 , 5	—0 4.23	— 1 55.3	15 23 51.5	+50 20.2	9.816	9.961
18 11 34 27	13	*3 , 6	—0 3.21	+ 0 50.1	15 26 17.92	+45 43 25.4	9.874	0.572
21 9 38 24	14	*3 , 6	+0 1.75	— 3 57.6	15 28 43.78	+41 9 37.4	9.785	0.496
Sept. 3 9 25 20	15	*3 , 6	+0 5.41	+ 0 13.2	15 39 49.59	+21 0 17.2	9.673	0.613
7 10 14 29	16	3	. . . . . .	+ 3 24.1	. . . .	+14 55.4	. . .	0.699
7 10 35 5	16	10	+1 20.86	. . . . .	15 43 29.1	. . . .	9.687	. . .
10 8 25 35	17	11 , 6	—0 9.80	+ 5 13.7	15 46 0.89	+10 58 6.5	9.617	0.660
12 8 31 52	18	8 , 6	+1 57.22	+ 3 17.8	15 47 49.11	+ 8 15 36.5	9.626	0.684
12 8 31 52	19	8	+1 18.94	. . . . .	15 47 49.21	. . . .	9.626	. . .
17 8 0 20	20	16 , 7	—0 31 32	+ 1 31.2	15 52 19.7	+ 1 55.5	9.605	0.718
Oct. 2 7 26 10	21	3	. . . . . .	+ 2 20.9	. . . .	—13 12.7	. . .	0.777
2 7 40 49	21	11	—0 21.11	. . . . .	16 6 25.0	. . . .	9.611	. . .
6 7 24 29	22	3	. . . . . .	— 0 51.2	. . . .	—17 7 51.2	. . .	0.779
6 7 36 58	22	10	—1 19.81	. . . . .	16 10 18.31	. . . .	9.677	. . .

Mean Places for 1890.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	15 12 1.1	+1.61	+76 6	+15.1	DM. 76 555
2	15 11 23.74	+1.62	+75 52 30.0	+15.1	Oe.A. 15302,3
3	15 20 15.28	+1.60	+75 15 7.2	+15.7	Schwerd's observations, 903
4	15 12 38.19	+1.34	+74 17 16.0	+15.5	Compared with Oe.A. 15180
5	15 12 55.10	+1.34	+74 11 3.5	+15.5	Compared with star 4
6	15 17 18.83	+0.93	+66 28 43.5	+15.1	Christiania Zones

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
7	15 17 52.10	+0.80	+62 52 7.3	+15.5	Helsingfors-Gotha A.G. 8330
8	15 18 55.81	+0.75	+60 4 43.4	+11.9	Helsingfors-Gotha A.G. 8333
9	15 19 29.01	+0.70	+57 18 6.6	+11.7	$\frac{1}{3}$(Oe.A.15338,9+2 H.-G.A.G.8340)
10	15 21 35.55	+0.69	+51 37 2.5	+11.3	Oe.A. 15365
11	15 22 46.9	+0.67	+51 41.2	+13.9	DM. 51° 2006
12	15 23 55.0	+0.66	+50 21.9	+13.7	DM. 50° 2176
13	15 26 20.51	+0.62	+45 42 21.9	+13.4	B.B. 45° 2291
14	15 28 41.43	+0.60	+41 13 22.6	+12.4	9ᴹ.5(comp. with ν^2 Bootis = Yar.6512)
15	15 39 43.57	+0.61	+21 0 26.3	+ 7.7	DM. 21° 2810 comp. with W.B. 15ʰ 885-8
16	15 42 7.9	+0.61	+14 51.9	+ 5.3	DM. 14° 2938
17	15 16 10.15	+0.54	+10 52 18.9	+ 3.9	W.B. 15ʰ 854
18	15 45 51.34	+0.55	+ 8 12 15.1	+ 3.6	W.B. 15ʰ 852
19	15 46 29.72	+0.55	+ 8 10 42.3	+ 3.6	W.B. 15ʰ 860
20	15 52 50.4	+0.58	+ 1 54.0	+ 2.6	DM. +2° 3025
21	16 6 18.9	+0.54	—13 15.0	— 1.7	SDM. —13° 4378
22	16 12 7.62	+0.53	—17 6 57.4	— 2.6	$\frac{1}{2}$(Lal. 29677+Oe.A. 15492)

* The $\Delta\alpha$ measured direct with micrometer.

Star 7. The place of this star from Oe.A. is 15ʰ 17ᵐ 52ˢ.11, +62° 51′ 18″.4 (1890.0). The DM. checks the declination of the A.G.

Star 8. The place from Oe.A. is 15ʰ 18ᵐ 55ˢ.82, + 60° 4′ 24″.6 (1890.0). There seems to be an error in the declinations of both stars in Oe.A.

Star 9. Oe.A. 15339 corrected by —1ˢ

Mt. Hamilton, 1890 *October.*

STAR-COMPARISONS.

	m s	′ ″
Star 4. — Oe.A. 15180	+6 44.75 (8)	—1 31.4 (3)
Star 5. — Star 4	+0 16.91 (16)	—6 12.5 (3)
Star 14. — Yar. 6512	+0 50 62 (26[2n])	—2 58.9 (6[2n])

The comet remained a faint object throughout the observations. In July and August it had a small stellar nucleus of the 13th magnitude and a faint diffused tail.

ERRATA IN FOLIE'S PRECESSION TABLES,

BY SIDNEY J. LOCHNER, ASSISTANT AT DUDLEY OBSERVATORY.

While using Table I of FOLIE'S *Douze Tables pour le Calcul des Reductions Stellaires*, the following errors were detected in addition to those noted in the introduction to that work.

Page	Argument	For	Read
	h m s		
6	0 22 5	9.10922	9.10932
8	0 35 5	9.30924	9.30934
12	0 59 44	9.53732	9.53722
17	1 21 30	18″.8995	18″.7995
17	1 27 50	18″.6994	18″.5994
19	1 30 50	18″.5997	18″.4997
19	1 39 20	18″.2999	18″.1999
26	2 1 33	9.830123	9.830133
26	2 6 00	2ʰ 0ˢ	2ʰ 6ᵐ 0ˢ
26	2 6 52	9.846878	9.846868
36	2 55 00	9.965916	9.965915
60	4 50 50	0.105029	0.106029
62	5 5 10	0.113364	0 113564
66	5 28 53	0.122999	0″.122099
67	6 29 50	9ᵐ	29ᵐ
68	5 37 40	0.124040	0.124049

CORRIGENDUM.

No. 227, p. 85, col. 2, for *X Cygni*, put χ *Cygni*.

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THE

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ON THE RELATIVE REFRANGIBILITY OF THE LIGHT OF *MARS* AND STARS,

BY W. L. ELKIN.

Prof. NEWCOMB has asked me to draw up for the *Astronomical Journal* a short account of an attempt made for him, with the Yale heliometer, to determine the relative refrangibility of the light of *Mars* as compared with that of an average star. Theoretically, owing to the deficiency of blue rays in the light of *Mars*, it should suffer a less refraction than do the stars; and, if the difference be sensible, it has an important bearing on the solar parallax determinations from *Mars*. Prof. NEWCOMB proposed to place two prisms of small refracting angle, acting in opposite directions, over the object-glass of the heliometer, thus measuring the sum of the refractions of the prisms by bringing the two images side by side. The prisms, which Prof. NEWCOMB ordered from BRASHEAR, and of which the cost was defrayed by a grant from the Bache fund, measured two inches by four, and produced a refraction of about $6\frac{1}{4}'$, corresponding to that caused by the atmosphere at 80° 20′ zenith-distance. They were mounted in front of the objective, placing semicircular diaphragms of two inches radius between prism and lens, and inclined at an angle of about 1° to the line of section of the object-glass. The two images of *Mars* when brought together were thus about tangent to each other, and, as the focal plane contained a pair of wires perpendicular to the direction of displacement of the semi-lenses, fairly accordant pointings could be made by bringing the two images between and parallel to these wires. What I attempted to observe was not the brightest part of the spectrum, nor the limits of its extent, but what I might call the center of gravity of the mass of light, this being in my opinion the only way of attaining the desired result. I was fully prepared to expect considerable systematic error in comparing in this manner a disk like *Mars* with stellar points, but I did not anticipate the result which did ensue, which was that I pointed upon a different part of the stellar spectrum according to the brilliancy of the star, the center of gravity of the images of the fainter stars appearing to my eye further towards the blue than that of the brighter ones. This is very plainly apparent from the following values of the observed displacement, the stars being all in the immediate neighborhood of *Mars* in June 1890, and each result depending upon four pointings.

Star			Mag.	Observed Displacement ″
URAN. ARG ,	*Scorpius*	13	2.4	748.54
	"	18	2.5	748.74
	Ophiuchus	28	2.6	749.25
	"	7	2.7	748.62
	Ophiuchus	9	3.3	748.55
	Scorpius	12	3.4	749.59
	"	61	3.4	749.87
	Ophiuchus	25	3.8	749.25
	Scorpius	20	4.4	749.18
	"	9	4.5	749.08
	"	38	4.5	749.17
	"	21	4.6	749.46
	Scorpius	39	5.2	749.21
	"	44	5.6	750.05
	"	40	5.7	749.79
	"	49	5.7	751.28
	Scorpius	25	6.0	749.01
	"	26	6.0	749.34
	"	19	6.2	751.83
	"	27	6.3	752.00
	Scorpius	45	6.9	751.95
	"	52	6.9	750.85
	"	42	7.0	751.50
	"	51	7.0	752.14

Taking the means of the groups indicated we have the values:

Mag. 2.55	Displacement, 748.79 ″
3.5	749.31
4.5	749.22
5.55	750.08
6.1	750.54
6.95	751.64

showing plainly the progressive discrepancy. In explanation of this the only thing which has occurred to me is that, to me, a faint star seems to have a bluish tinge, so that my eye is apparently more sensitive to faint blue rays than faint red ones. I believe this is a generally observed phenomenon.

The similar observations on *Mars*, made simultaneously with the above, are as follows:

	″
Mars, observed displacement,	748.19
	748.30
	748.28
	748.38
	749.00
	748.99
	748.85
	748.89
	748.52
	748.73
	748.80
	748.20
Mean,	748.59

and after noticing the systematic magnitude-error, the following with *Mars* dimmed down about four magnitudes by means of a wire gauze screen:

	″
Mars, observed displacement,	748.57
	748.84

In this latter case, however, the image of *Mars* was rather sharpened up than otherwise, and I hardly think the effect comparable with an equivalent diminution of the light of a star.

From these results it is not easy to draw any conclusion as to the relative refrangibility of the light of *Mars* and a star, beyond that the difference cannot be very large. One difficulty lies in deciding upon the magnitude to be assigned to *Mars* for comparison with the star-results. As a whole, *Mars* was much brighter than any of the stars compared, but the intrinsic brilliancy of its spectrum was probably not very much greater than that of a second-magnitude star. The difference of refraction between *Mars* and the first group of stars of the mean magnitude 2.55 is only $0''.20$, or about $\frac{1}{2700}$ of the whole amount, and is really, in view of this uncertainty, and the further possible systematic error in comparing a planetary disk and a stellar point, hardly larger than its probable error, in my estimation.

Yale University Observatory, New Haven, Conn., 1890 *November*.

EPHEMERIS OF COMET *a* 1890 (*BROOKS, March 19*).

By W. W. CAMPBELL.

This comet remains favorable for morning observations during several months. From an observation made here this morning, the correction to my ephemeris in the *Astronomical Journal* no. 222, was: $\Delta\alpha = -7^s.0$, $\Delta\delta = -30''$. The following continuation of the ephemeris will therefore suffice for purposes of observation.

Ephemeris for Greenwich Mean Midnight.

1890	App. α	App. δ	log r	log Δ	Br.
	h m s	° ′			
Nov. 14	13 11 37	+25 50.1	0.4405	0.5072	0.42
16	11 38	25 49.4			
18	11 35	25 49.6	0.4456	0.5044	0.42
20	11 30	25 50.5			
22	11 21	25 52.3	0.4507	0.5011	0.42
24	11 9	25 54.8			
26	10 52	25 58.2	0.4558	0.4974	0.41
28	10 32	26 2.3			
30	10 8	26 7.3	0.4608	0.1933	0.41
Dec. 2	13 9 39	+26 13.0			
Dec. 4	13 9 6	+26 19.5	0.4658	0.4888	0.41
6	8 28	26 27.0			
8	7 45	26 35.3	0.4707	0.4840	0.41
10	6 56	26 44.3			
12	6 2	26 51.2	0.4757	0.4789	0.41
14	5 2	27 4.9			
16	3 56	27 16.4	0.4806	0.4736	0.41
18	2 44	27 28.8			
20	13 1 25	27 42.2	0.4854	0.4681	0.41
22	12 59 59	27 50.6			
24	58 26	28 10.6	0.4903	0.4626	0.41
26	56 45	28 25.6			
28	54 57	28 42.0	0.4951	0.4569	0.42
30	53 1	28 58.4			
32	12 50 57	+29 16.1	0.4998	0.4514	0.42

Ann Arbor, 1890 *Nov.* 14.

Erratum. — No. 222, p. 45, last line, *for* $\cos\delta \, . \, \Delta\alpha = -4^s.5$, *read* $\cos\delta \, . \, \Delta\alpha = 4^s.5$.

OBSERVED MAXIMA AND MINIMA OF VARIABLE STARS,

By PAUL S. YENDELL.

Y Ophiuchi.

The variability of this star was announced by Sawyer in this *Journal* Vol. 9, p. 138. I began observations upon it 1890 May 16, from which date until October 15 it was observed 59 times; bad breaks occur in the series, caused by unfavorable weather; but three maxima and five minima were observed, in addition to which, two maxima were deduced by the use of Sawyer's light-scale and mean curve.

These results substantially confirm Sawyer's elements, two of the minima, however, being markedly discordant, as will be seen below; in four cases out of the five minima the phase appeared to be sharply marked by a decided inflexion of the light-curve, though its general character for about two-thirds of the interval between successive maxima seems to be very flat.

The observed times are as follows, the maxima marked *c* having been deduced by the use of the mean light-curve.

	Maxima			Minima		
E	1890	w	O—C	1890	w	O—C
161	May 14.58	3	+0.12 *c*			
166	June 18.60	4	+0.86			
167	July 4.40	4	—0.48	June 27.0	2	—0.03
168	22.40	3	+0.38	July 11.5	1	+0.33
169				Aug. 4.5	1	+1.19
170				17.9	4	+0.45
171				Sept. 1.2	1	—2.39
173	Oct. 15.95	2	+0.23 *c*			

Gore's New Variable in *Hercules*.

This star has recently passed a bright maximum; a minimum at about 7M.1 took place August 11, and a maximum of about 6M.0 on October 10; when last observed, November 6, it had again fallen to 6M.8.

U Aquilae.

Observations of *U Aquilae* were begun 1890 July 6, between which time and October 11, thirty-three observations were obtained; from these observations four maxima and four minima are deduced by the single light-curves, as follows:

Observed Maxima	w	Observed Minima	w
1890 July 12.0	4	1890 July 24.0	2
19.4	3	Aug. 7.0	3
Aug. 15.4	1	Sept. 4.3	4
31.0	3	18.3	1

RR Cygni.

I have observed this star of Espin's seventeen times during the season. On June 16, when first looked at, it was estimated to be of the ninth magnitude, being = the DM. star closely s.f., which appears to be +44°3573, 9M.1; it rose slowly and irregularly to about 8M.7, and passed a pretty distinctly indicated maximum on August 20; its decrease was more rapid and regular than its increase, it having declined by September 30 to about 9M.4, at which light it remained when last observed on November 13.

T Herculis.

Six observations of this star, obtained between September 18 and October 18, indicate that a maximum was passed September 30. The star's light at maximum is estimated at 7M.6.

Observations were made on a number of other variables of long period, but the repeated long breaks in the series made by unfavorable weather have broken up most of the lines of observations so badly that no results can be obtained from them.

Dorchester, Mass., 1890 *Nov.* 15.

OBSERVATIONS OF COMET *d* 1890, (*D'ARREST*),

MADE AT THE U.S. NAVAL OBSERVATORY WITH THE 9.6-INCH EQUATORIAL,

By Prof. E. FRISBY.

[Communicated by the Superintendent.]

Washington M.T.	*	No. Comp.	☄—*		☄'s apparent		log *p*Δ	
			Δα	Δδ	α	δ	for α	for δ
d h m s			m s	′ ″	h m s	° ′ ″		
Oct. 14 7 56 18.0	1	20 , 5	+0 25.42	— 3 21.1	19 45 21.95	—27 25 0.6	9.359	0.889
17 7 11 31.2	2	20 , 4	—2 37.43	—12 9.1	19 57 35.87	—27 44 26.0	9.126	0.902
18 8 59 40.1	2	10 , 2	+1 45.24	—17 20.1	20 1 58.53	—27 49 37.0	9.541	0.862
Nov. 1 8 2 18.1	3	10 , 2	+0 34.41	+ 1 32.6	20 58 24.17	—27 53 25.8	9.377	0.889
5 7 25 53.0	4	20 , 5	+0 20.28	+ 6 40.9	21 13 15.35	—27 33 36.6	9.210	0.899
6 8 21 22.6	5	9 , 2	+0 40.10	+ 5 40.1	21 17 40.28	—27 26 51.5	9.441	0.881

Mean Places for 1890.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	19 44 54.84	+1.69	—27 21 39.1	—0.4	⅓(Gould + Stone + Yarnall)
2	20 0 11.56	+1.74 +1.73	—27 32 17.0	—0.1 +0.1	Gould, Zone Catal. XIX, 2398
3	20 57 48.05	+1.71	—27 58 0.0	+1.6	½(Gould + Yarnall)
4	21 13 23.21	+1.86	—27 40 19.5	+2.0	½(Gould + Yarnall)
5	21 16 58.02	+1.86	—27 32 36.6	+2.0	Gould, Zone Catal. XXI, 506

FILAR-MICROMETER OBSERVATIONS OF COMET *b* 1890 (*COGGIA*),

MADE WITH THE 12-INCH EQUATORIAL OF THE LICK OBSERVATORY,

BY E. E. BARNARD.

1890 Mt. Hamilton M.T.	∗	No. Comp.	☄ — ∗ Δα	☄ — ∗ Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
h m s			m s	′ ″	h m s	° ′ ″		
July 24 8 57 41	1	18 , 6	—1 1.61	+ 7 56.2	9 31 14.68	+39 52 52.7	9.747	0.787
25 9 7 31	2	12 , 5	+3 6.25	+ 4 2.5	9 40 37.67	+39 1 53.6	9.738	0.777
27 9 7 17	3	10 , 5	+2 24.46	+ 0 37.4	9 52 31.2	+37 13.1	9.735	0.783
28 8 45 25	4	3	. . . . . .	— 2 4.9	. . . .	+36 27 5.2	. . .	0.754
8 58 23	4	6	+1 9.41	. . . . . .	9 58 12.40	. . . .	9.732	. . .
29 8 33 23	5	2	. . . . . .	—12 2.8	. . . .	+35 34 52.2	. . .	0.735
8 57 30	5	6	+2 40.39	. . . . . .	10 3 36.16	. . . .	9.729	. . .
30 8 44 30	6	2	. . . . . .	— 3 23.2	. . . .	+34 44.5	. . .	0.751
8 51 35	6	3	+0 6.69	. . . . . .	10 8 50.0	. . . .	9.736	. . .
31 8 52 51	7	2	. . . . . .	— 1 46.4	. . . .	+33 48 24.6	. . .	0.761
Aug. 1 8 36 24	8	4 , 8	—0 3.98	— 4 9.6	10 18 31.9	+32 56.4	9.733	0.739
3 8 43 6	9	10 , 5	+0 53.73	— 9 2.6	10 27 11.13	+31 50 27.2	9.686	0.801
6 8 43 18	10	6 , 4	+0 48.30	+ 1 27.7	10 40 26.08	+28 34 5.0	9.713	0.747
8 8 47 7	11	8 , 5	+0 33.31	+ 4 2.2	10 48 8.19	+26 51 42.1	9.699	0.761
10 8 39 35	12	1 , 2	+0 25±	— 0 12.8	10 54 20±	+25 9.7	9.697	0.757
12 8 35 20	13	1	. . . . . .	— 0 37.3	. . . .	+23 35 13.0	9.695	0.757
13 8 39 58	14	1	. . . . . .	+ 5 45.1	. . . .	. . . .	9.691	0.754

Mean Places for 1890.0 of Comparison-Stars.

∗	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	9 35 19.92	—0.63	+39 44 51.2	+5.3	W.B 9^{h} 699
2	9 37 32.03	—0.61	+38 57 46.0	+5.1	W.B. 9^{h} 762, 3
3	9 50 10.3	—0 55	+37 12.1	+5.1	DM. 37° 2019
4	9 57 3.50	—0.51	+36 29 5.0	+5.1	W.B. 9^{h} 1166, 7
5	10 0 56.25	—0.48	+35 46 50.3	+5.0	21 *Leonis Min.* = Yar. (F) 4299
6	10 8 43.9	—0.45	+34 44.8	+5.0	DM. 34° 2103
7	10 16 31.77	—0.41	+33 50 6.0	+5.0	W.B. 10^{h} 282
8	10 18 39.3	—0.38	+33 0.6	+5.0	DM. 33° 1982
9	10 26 17.78	—0.38	+31 59 21.8	+5.0	B.B. 32° 2045
10	10 39 38.18	—0.40	+28 32 32.5	+4.8	W.B. 10^{h} 767
11	10 47 35.24	—0.36	+26 47 35.5	+4.4	W.B. 10^{h} 927
12	10 53 55.0	—9.28	+25 9.8	+4.1	DM. 25° 2324
13	11 2 10.03	—0.25	+23 36 16.5	+3.8	W.B. 10^{h} 1214
14	This star not identified. It was 8^{M}-9^{M}, and followed the comet by 20′.				

NOTE.

At the last few observations, the comet was seen for only a few minutes. It was still bright, but set too early to permit accurate observations.

The above positions are all that were obtained here of this comet, except two observations made on July 22 and 23 by Mr. CAMPBELL, and which were printed in *A.J.* 223.

Mt. Hamilton, 1890 *October*.

NEW ASTEROIDS.

Mr. BERBERICH of the *Berliner Jahrbuch* has found that observations made by CHARLOIS, Oct. 3, and PALISA, Oct. 11 and 22, for position of the asteroid no. 298, discovered by the former, Sept. 9, give an orbit entirely different from that deduced from M. CHARLOIS's observations of Sept. 9, 10, 16, — these September observations being consistent with each other, as also are the October ones. Since the two groups of observations thus clearly belong to distinct planets, he proposes that the object observed in October, and recognized as new after no. 299 had been found by PALISA, be designated as no. 300. Dr. **Krueger** gives his indorsement to this notation, and the object will be thus denoted.

Mr. **Berberich** publishes, in the *Astr. Nachr.* 3004, the circular orbits, provisionally deduced by him. They hold for Berlin M.T., and the mean equinox of 1890.0

	No. 298 From September Observations	No 300 From October Observations
$T =$	1890 Sept. 16.5	1890 Oct. 22.5
$u =$	353° 23′.16	330° 25′.60
$\Omega =$	8 27 .42	39 16 .64
$i =$	4 59 .96	0 51 .54
$n =$	1072″.78	613″.21
$\log a =$	0.34632	0.50827

A planet, 13^{M}, was discovered Nov. 16, by **Palisa**, at Vienna, in the position,

Nov. 16.4413. $\alpha = 3^h\ 12^m\ 50^s.5$, $\delta = +10°\ 14'\ 33''$. Daily motion, —52^s in α, and 3′ southward.

This will be asteroid no. 301.

COMET *e* 1890.

A bright comet was discovered November 15, by **Zona**, at Palermo. The position as telegraphed from Kiel, was

Nov. 15.3963 Greenw. M.T. $\alpha = 5^h\ 35^m\ 54^s.8$, $\delta = +33°\ 23'$. Daily motion, —5^m 32^s in α, and 17′ northward.

An observation made by **Barnard**, Nov. 17, was telegraphed from the Lick Observatory:

Nov. 17.6833 Greenw. M.T. $\alpha = 5^h\ 23^m\ 10^s.5$, $\delta = +33°\ 55'\ 44''$.

Mr. **Ritchie**, of the *Science Observer*, has kindly communicated the following observations by Mr. **Wendell** at the Cambridge Observatory.

Camb. M.T.	α	δ
h m s	h m s	° ′ ″
Nov. 18 14 17 6	5 17 57.5	+34 7 18.5
19 8 35 9	5 12 24.4	34 18 33.3
20 9 46 31	5 6 16.9	+34 29 45.4

From the observations made at Palermo, Nov. 15, Mt. Hamilton, Nov. 17, and Cambridge, Nov. 18, Rev. G. M. **Searle** has computed the elements:

$$
\begin{aligned}
T &= 1890 \text{ Aug. } 9.2340 \text{ Greenw. M.T.} \\
\Omega &= 85°\ 33'\ 52'' \\
i &= 154\ \ 34\ \ 18 \\
\omega &= 332\ \ 45\ \ 13
\end{aligned}
\left.\vphantom{\begin{aligned}a\\b\\c\end{aligned}}\right\}\text{Mean Eq. 1890.0}
$$

$$\log q = 0.315440$$

For the middle place, (O—C) $\Delta\lambda = +2''$, $\Delta\beta = +2''$.

Ephemeris for Greenwich Mean Time.

	App. α	App. δ	log Δ	Br.
	h m	° ′		
Nov. 24.5	4 43.1	+34 59	0.1650	0.98
28.5	4 19.3	35 9	0.1699	.94
30.5	4 7.7	35 6	0.1738	.91
Dec. 2.5	3 56.3	35 0	0.1788	.88
4.5	3 45.3	34 49	0.1847	.85
6.5	3 34.7	34 34	0.1914	.82
8.5	3 24.6	34 16	0.1989	.79
10.5	3 15.0	33 56	0.2071	.76
12.5	3 6.1	33 33	0.2159	.72
14.5	2 57.3	33 9	0.2251	.69
16.5	2 19.3	32 43	0.2349	.65
18.5	2 41.9	32 17	0.2448	.62
20.5	2 35.0	31 50	0.2541	.58
22.5	2 28.7	31 23	0.2539	.55
24.5	2 22.7	30 57	0.2755	.51
26.5	2 17.2	+30 32	0.2872	0.48

THE NOVEMBER *LEONIDS*, 1890.

By EDWIN F. SAWYER.

During a watch of seventy-five minutes on Nov. 14, from 14^h to 15^h 15^m, in a perfectly clear sky, only seven meteors were recorded, of which three were probably members of the *Leonid* meteor stream. Of the seven seen, six paths were mapped as follows:

No.	Camb. M.T.	Mag.	Observed Path From R.A.	Observed Path From Decl.	Observed Path To R.A.	Observed Path To Decl.	Length of Path	Wt.	Remarks
	h m		°	°	°	°	°		
1	14 15	5	141	+ 10	139	+ 5	5	3	Rapid: *Leonid*
2	14 33	2	152	— 2	161	— 5	9	1	Rather slow: ½ second
3	14 42	1	152	+ 10½	152½	+ 7½	3	1	Rapid; greenish streak: ¼ second; *Leonid*
4	15 0	2	166	— 8	171	— 14	8	3	Rapid; *Leonid*
5	15 2	5	130	+ 7½	135	+ 7½	5	3	Rapid; from [illegible] *Hydrae*
6	15 10	5	147	+ 7½	154	+ 7	5	3	Rapid

View restricted to one-sixth of the visible heavens. Center of observation, *Leo*.

Brighton, Mass., 1890 *November* 16.

CORRECTIONS TO CHAUVENET'S ASTRONOMY,

BY HERBERT A. HOWE.

The following errata have been noticed in the last (the fifth) edition of CHAUVENET'S Astronomy. The errors in the last sentence on page 689 of Vol. I, can be corrected by substituting λ', λ'' and β for α', α'' and δ respectively, and the word "longitudes" for "right-ascensions."

Mr. ALBERT S. FLINT has called my attention to the fact that the statement made in the first three lines of page 402 in Vol. II, is erroneous.

VOL. I.

p. 61, line 3,	*for*	0.0027391	*read*	0.0027391
85, line 8,	"	Mar. 6	"	Mar. 5
106, line 9 from below,	"	$\zeta - p$	"	$\zeta + p$
159, line 5 from below,	"	0.00029411	"	0.000294211
179, last line	"	$5280\,d \sin 1'$	"	$5280\,d \sin 1''$
187, Fig. 23,	"	M and N (at right-hand end of lines)	*read*	M' and N'
301, line 7 from below,	"	zenith distance	*read*	reduction of the zenith distance.
374, line 9 from below,	"	A,	*read*	A'
385, line 5,	"	$L'' - L$	"	$L'' - L'$
429, Fig. 36,	"	A (at upper end of AC)	*read*	A'
483, line 2,	"	$\cos(Q - E$	*read*	$\cos(Q - E)$
562, line 8,	"	minimum	"	minimum
598, line 10 from below,	"	$T_0 - h$	"	$T_0 + h$
607, line 2 from below,	"	0.0000875	"	0.00000875
610, line 9 from below,	"	ψ	"	ψ_1
614, line 5,	"	$V'_2\,D$	"	$V'_2\,D'$
615, last line,	"	$\frac{1}{2}(\varepsilon' + \varepsilon)$	"	$\frac{1}{2}(\varepsilon'_1 + \varepsilon_1)$
p. 621, lines 10 to 13 from below,	*for*	ζ and ζ'	*read*	z and z'
637, line 7 from below,	*for*	earth's,	*read*	sun's
641, line 3	"	earth,	"	sun
648, line 13	"	(☾ + r),	"	(⊙ + r)
661, line 9	"	$\dfrac{\tan^4 \frac{1}{2}\mu}{\sin 1''}$	"	$\dfrac{\tan^4 \frac{1}{2}\mu}{2 \sin 1''}$
684, line 4 from below,	"	$(\zeta'_1 \mp k)^3$	"	$(\zeta'_1 \pm k)^3$
685, line 7	"	ζ_1	"	ζ'_1
699, line 3 from below,	"	-0.0677	"	$+0.0677$

VOL. II.

p. 25, line 15 from below,	*for*	98.2	*read*	98.3
39, line 2 from below,	"	N	"	E
117, line 13 from below,	"	$\gamma' = \gamma$	"	$\gamma' - \gamma$
128, line 6	"	longer	"	longest
334, line 16	"	geocentric	"	heliocentric
378, line 8	*for*	$\sin\delta \sin\gamma - \cos\delta \cos\gamma \cos(\tau - \theta)$	*read*	$-\sin\delta \sin\gamma + \cos\delta \cos\gamma \cos(\tau - \theta)$
387, line 13 from below,	*for*	$\cos\tau$	*read*	$\cos\tau_1$
388, line 12	"	hour	"	declination
414, line 14	"	$u' + v$	"	$u' + u$
423, line 3	"	$\tan^2\delta$	"	$\tan^2\delta_0$
426, line 5 from below,	insert	(at beginning of line.		
427, line 13 from below,	insert	(318) at end of line.		
434, line 7	*for*	$\dfrac{2S}{\sigma \tan\mu}$	*read*	$\dfrac{2S'}{\sigma \tan\mu}$
445, lines 1 and 4 from below,	*for*	d	*read*	$2d$
446, lines 2 and 3	"	d^2	"	$4d^2$

University of Denver, 1890 *Nov.* 8.

OBSERVATION OF COMET *e* 1890,

MADE WITH THE 15-INCH EQUATORIAL OF THE HARVARD COLLEGE OBSERVATORY,

BY O. C. WENDELL, ASSISTANT.

Communicated by Professor EDWARD C. PICKERING, Director.

1890 Cambridge M.T.	*	No. Comp.	☄ — *		☄'s apparent		log $p\Delta$	
			$\Delta\alpha$	$\Delta\delta$	α	δ	for α	for δ
d h m s			m s	' "	h m s	° ' "		
Nov. 18 9 32 35	1	5	—0 19.86	+ 2 7.8	5 17 57.55	+34 7 17.6	n9.651	0.475
19 8 35 9	2	5	—1 12.86	+ 9 18.0	5 12 24.10	+34 18 33.3	n9.697	0.563
20 9 46 31	3	5	—2 23.38	+11 34.7	5 6 16.87	+34 29 45.4	n9.608	0.400
21 9 25 38	4	6	—1 32.33	+ 7 41.6	5 0 28.63	+34 38 58.5	n9.626	0.420
22 9 14 45	5	5	+3 30.46	—10 47.9	4 54 36.29	+34 47 12.8	n9.629	0.424

Mean Places for 1890.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ' "	"	
1	5 18 13.81	+3.60	+34 5 6.0	+3.8	Weisse's Bessel (2) 5h 439
2	5 13 33.63	+3.63	+34 9 10.9	+4.4	" " 5h 301
3	5 8 36.59	+3.66	+34 18 5.7	+5.0	" " 5h 151-2
4	5 1 57.27	+3.69	+34 31 11.3	+5.6	" " 4h 1375
5	4 51 2.11	+3.72	+34 57 54.5	+6.2	" " 4h 1089

REMARKS.

The observations have been corrected for proper motion. Correction for refraction inappreciable.

Nov. 18. Diameter of total nebulosity 1'. Some central condensation, but nucleus not quite stellar.

Nov. 19. Comet well seen. Nucleus rather sharply defined.

Nov. 20. Nucleus fairly well defined.

Nov. 21. Comet rather faint, but pretty well defined.

Nov. 22. Comet faint in moonlight.

CONTRIBUTIONS TO THE KNOWLEDGE OF THE INEQUALITIES IN THE PERIODS OF THE VARIABLE STARS,

By S. C. CHANDLER.

IV.

7120. χ *Cygni*.

Although this variable has been under observation for two hundred years, without serious gaps in the series of known maxima, except near the beginning of the present century, the true law of the rather complicated variations in its period is still far from our reach. From the date of its discovery up to about 1850, the mean value of the period was about 406 days, without decided tendency to a progressive rate of change, but with large irregular or periodic variations. **Argelander** made many attempts to reduce these to a systematic expression, as he had already done in the case of *o Ceti*, but gave over the attempt after experimenting with various inequalities of 8½, 100 and 62 periods' duration. Soon afterwards an important change took place in the period, and **Schönfeld** remarked in 1872 that had the star been only recently discovered, we should have concluded with apparent certainty that the period is 409.8 days, which represents well all the maxima since 1842. In his Second Catalogue the latter employed an approximate uniform period of 406.5 days, as the best average value since discovery, making no attempt to represent by a formula the large systematic deviations therefrom, which are shown in the column O—C′ in the table below; but remarking that they indicate a general lengthening since discovery, combined with unknown periodical terms. This form of hypothesis I have adopted in the numerical expression of the inequalities; and the elements

$$\left.\begin{array}{l}\text{Max. } 1763 \text{ June } 3^{d}.5 \\ \text{Min. } 1762 \text{ Dec. } 14.0\end{array}\right\} +406^{d}.02\,E+0^{d}.0075\,E^2 + 25^{d}.0 \sin(5^\circ E+272^\circ)$$

are to be inserted in the next edition of my catalogue. The representation of the observed maxima by this formula is far from satisfactory, as will be seen in the last column (O—C) of the table. We are manifestly far from the true development of the irregularities. This solution is of so provisional a character that it is not worth while to give the voluminous data in detail at present; but instead, I present the following condensed statement of normal epochs formed by suitably grouping the observed maxima in the manner shown in the first five columns of the table. The column (O—C′) contains the deviations from the elements of **Schönfeld**'s catalogue; and (O—C) those from the elements with the quadratic and periodic terms, above given.

Table of Normal Epochs of Maxima.

E	Dates	No.	E	O—C′	O—C
				d	d
— 68 — 61	1687–1695	6	— 64	+37.1	+ 9.3
— 56″— 49	1701–1709	6	— 52	+22.4	—13.0
— 46″— 40	1712–1719	6	— 43	+22.0	—18.5
— 34″ — 25	1725–1735	1	— 30	+27.0	— 0.3
— 23″— 14	1737–1747	3	— 20	+ 4.0	+ 2.9
— 6″— 1	1756–1758	3	— 5	—34.5	+ 0.9
+ 18″ + 32	1783–1799	4	+ 22	— 8.4	+ 4.1
+ 47″ + 52	1815–1821	4	+ 49	— 5.0	+ 5.7
+ 53″ + 60	1822–1830	7	+ 56	—27.6	— 4.0
+ 70″ + 77	1841–1849	8	+ 74	—29.2	+ 4.8
+ 79″ + 85	1851–1857	7	+ 82	—28.8	— 9.5
+ 86″ + 92	1859–1865	6	+ 89	— 7.2	— 7.6
+ 93″ + 99	1867–1873	7	+ 96	+41.2	+20.0
+100 +105	1874–1880	5	+103	+35.4	— 2.7
+106 +110	1880–1886	5	+108	+44.3	— 1.3

The epoch of minimum assigned in the elements is derived from five observed minima by **Schmidt** between 1867 and 1878.

As in the previous articles in this series I give the next few computed maxima and minima.

Maxima	Minima
1890 June 22	
1891 Aug. 5	1891 Feb. 12
1892 Sept. 12	1892 Mar. 25
1893 Oct. 24	1893 Jan. 25

OBSERVATIONS OF COMET *e* 1890 (ZONA),

MADE AT THE U. S. NAVAL OBSERVATORY WITH THE 9.6-INCH EQUATORIAL.

By Prof. E. FRISBY.

[Communicated by the Superintendent.]

Washington M.T.	⁎	No. Comp.	☄′ — ⁎ Δα	☄′ — ⁎ Δδ	☄ 's apparent α	☄ 's apparent δ	log pΔ for α	log pΔ for δ
d h m s			m s	° ′ ″	h m s	° ′ ″		
Nov. 17 11 41 11.2	1	15 , 3	+2 29.50	+1 35.0	5 23 3.40	+33 55 41.7	*n*9.430	0.086
18 11 26 33.9	2	23 , 5	—0 37.52	+3 28.8	5 17 31.80	+31 7 51.4	*n*9.438	0.083
11 26 33.9	3	23 , 5	—0 15.76	+2 42.3	5 17 31.80	+31 7 52.2		
20 9 47 26.8	4	30 , 6	+0 1.07	—6 32.7	5 6 10.16	+31 29 20.2	*n*9.650	0.309
22 17 5 55.0	5	20 , 4	+1 26.86	—8 14.1	4 52 32.77	+34 49 27.0	9.708	0.465

Mean Places for 1890.0 of Comparison-Stars.

*	α	Red to app. place	δ	Red. to app. place	Authority
	m s	s	° ′ ″	″	
1	5 20 30.35	+3.55	+33 51 3.1	+3.6	Bonn VI, 33° 1019
2	5 18 5.66	+3.66	+31 4 18.7	+3.9	Weisse's Bessel V, 136
3	5 18 13.90	+3.66	+34 5 6.1	+3.8	" " 139
4	5 6 5.72	+3.67	+34 35 47.7	+5.2	" " 65
5	4 51 2.19	+3.72	+34 57 34.5	+6.6	" " IV, 1089

CONTINUED EPHEMERIS OF COMET d 1890 (*D'ARREST*),

By Rev. G. M. SEARLE.

Gr. Midnight	App. α	App. δ	log Δ	Br.	Gr. Midnight	App. α	App. δ	log Δ	Br.
	h m s	° ′				h m s	° ′		
Nov. 28	22 34 6	—23 37.0	0.1169	0.31	Dec. 10	23 10 12	—20 40.0	0.1637	0.23
Dec. 2	46 33	—22 40.6	0.1325	0.28	11	23 21 26	—19 37.0	0.1792	0.21
6	22 58 35	—21 41.1	0.1482	0.26					

COMET f 1890.

A faint comet was discovered Nov. 16, by Spitaler, at Vienna, in the position,

Nov. 16.6435 Greenw. M.T. $\alpha = 5^h\ 27^m\ 16^s.9$, $\delta = +33°\ 37'\ 16''$. Daily motion, north preceding.

No observation since the discovery appears to have been made, up to Nov. 26, either in America or in Europe.

NOTICE.

The Editor has been requested to give notice of a Memorial, which it is proposed to establish in honor of the late Father Perry, of Stonyhurst, England, by providing the Observatory at that place with a 15-inch telescope. Those desiring to contribute are invited to send their donations to Arthur Chilton Thomas, Esq., Marldon Chambers, 30 North John Street, Liverpool.

CORRIGENDUM.

No. 228, p. 95, M.T. Oct. 6, *for* $7^h\ 24^m\ 29^s$, *put* $7^h\ 22^m\ 29^s$.

ADVERTISEMENT.

A volume of the *Astronomical Journal* consists of twenty-four numbers, with table of contents and alphabetical index. The price of subscription is $5.00, *payable in advance*, to which is to be added the expense of postage, when the address is to countries not in the international postal union.

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No discount is made to booksellers; but remittances can be conveniently sent by postal money-order to the Editor, at Cambridge, Massachusetts. If made by checks, it is requested that these be drawn upon some bank in the New England States, or in the cities of New York, Philadelphia, Washington or Chicago.

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Advertisement.

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THE

ASTRONOMICAL JOURNAL.

No. 230.

VOL. X. BOSTON, 1890 DECEMBER 8. NO. 14.

THE CORDOBA DURCHMUSTERUNG,

By JOHN M. THOME,

Director of the Argentine National Observatory.

During the past five years our efforts have been devoted, mainly, to the extension of the Southern Durchmusterung, from the limit to which it had been carried by Prof. SCHÖNFELD; or, rather, from the beginning of —22°, so as to have that belt in common with SCHÖNFELD's great work, for direct comparison of results. Up to the present, we have made more than a million of observations of objects situated in the belt between —22° and —42°, which have all been reduced to a common mean epoch (1875.0), and in the course of a few months the final revision for that entire region will have been completed. The progress of the work has been very much delayed by the great amount of cloudy weather and semi-transparent atmosphere, which tended to break up a night's work into isolated patches, of no practical value except as checks, and has compelled us, frequently, to triplicate, and even quadruplicate, our observations in certain regions.

The telescope employed is a small equatorial by ALVAN CLARK & SONS, of 12.5 centimeters aperture, and 168 focal length, with an eye-piece magnifying 15 times, showing stars to the 10½ magnitude under the best conditions of sky, in dark field. It is mounted in the small dome over the north entrance to the Observatory. Its glass scale is ruled to 10′ over an extreme width of field of 80′, permitting the observation of zones of only one degree in width. No illumination has ever been used for the scale during the observations, and these have always been limited to dark sky, except for a few nights, just after new moon. Pointings are made by means of circles divided to 30′ in declination, and 2^m in right-ascension, subdivided by verniers to 1′ and 4^s respectively. The observing-chair can only be used when the telescope is inclined at angles greater than 30° of zenith-distance; and, with few exceptions, our observations have been made with the telescope inclined from 35° to 45°.

The transits are recorded electrically upon a Hipp chronograph, which is in an adjoining room. The recorder is seated at a table in the room beneath the dome, with the circuit-breaking chronometer at his side, and notes the scale-readings and magnitudes as they are called out by the observer, and also the times of beginning and ending of zones and intermediate rattles. His record is made with a fountain pen directly upon the reduction-sheets. These contain columns for the chronographic record, scale-readings, magnitudes, mean places and magnitudes for 1875.0 from the various catalogues used in identifying, and, finally, our observations reduced to 1875.0. At intervals of every 15 or 20 transits, the observer calls out "rattle," which he records upon the chronograph, and which the assistant also indicates upon the sheets, thus dividing the observations into groups, and guarding against the continuance of an error in either record. During the first years we employed a "sounder" to enable the recorder to hear and keep in tally with the chronograph-taps. For this purpose the ordinary observing-key was converted into both a make-circuit and break-circuit apparatus, operated by a single pressure of the thumb. The few involuntary taps could thus usually be detected and indicated by the observer himself, but no benefit was derived from the arrangement in the crowded regions of the milky way, where zones of 1200 stars to the hour were not infrequent, and it became literally impossible for either observer or recorder to take account of the taps, and the incessant repetition of these was rather confusing. The discordances between records have, besides, been comparatively few, and in nearly all cases they could be cleared up by the duplicate zones. The zone containing the largest proportional number of stars extends from $7^h\,55^m\,10^s$ to $8^h\,49^m\,50^s$, and from 30° 40′ to 31° 20′, and contains 1254 stars, all observed without a single discrepancy in the records. This is at the rate of 1376 stars per hour for a zone of 40′ in width, or 160 stars per square degree.

As our zones never exceed a degree in width, there is no need of plus and minus distinctions for north and south field, and we simply call the scale-reading, — from 20 to 80, going south. The magnitudes are estimated to quarters. In the crowded regions it became imperative to shorten the observer's notes to the utmost, especially for the more numerous classes, and we adopted the following method. The scale-reading is always called first. If it is unaccompanied by a magnitude, it signifies the class 10, and is left in blank by the recorder; if accompanied by a 3, it is so recorded, and signifies 9.7; by a 2, the 2 is recorded, and is translated 9.5; by a 1, it means 9.3, by a 9, 9.0. For stars brighter than 9, the whole magnitude is always given; 8^3 signifies 8.7; 6^2, 6.5. In the beginning we further distinguished the stars fainter than 10 by an *a*, but owing to the additional strain that this imposed upon the recorder, and his liability to mistake the *a* for an 8, the custom was discontinued.

The zones are one hour long, and have laps of $10'$ in declination, and 1^m in R.A. In the milky way they are only $40'$ wide, and have equal laps. The laps in declination of the revision-zones fall in the middle of the original zones. During the past year I have diminished the laps in declination to $5'$, by the aid of a programme containing the times, magnitudes and places upon the scale of five or six stars in each hour, selected usually from among the fainter ones given in the Cordoba Zone-Catalogue. As the transits of these stars approach the recorder calls out the scale reading and magnitude, and the observer has thus furnished him a check upon his limits, and also an indication of the relative clearness of the sky during the night, or upon different nights, and can adhere more closely to a consistent scale in his estimates of magnitude. By this means, also, any isolated patches can be exactly fitted into their places without loss, and we can select possible nights from among the bad ones. As the estimates for the Zone-Catalogue were only made to half-magnitudes, it happens that sometimes they are in error by that amount, but these cases are easily detected, and do not influence our estimates. Down to the 9th magnitude, the magnitudes as given in the Zone-Catalogue, are remarkably close in my opinion, considering the stress under which they were made; but the $9\frac{1}{2}$s should be distributed about equally between 9, $9\frac{1}{4}$ and $9\frac{1}{2}$, and the 10s are correct only in indicating that the object is fainter than $9\frac{1}{4}$, and I think there is no 10th magnitude in the catalogues.

A night's work, in view of the press of official duties during the day, and of the extent of our undertaking, has never exceeded six hours, and the observations have all been made in alternate zones by myself and Mr. Richard H. Tucker, Jr., first assistant, except for six months of last year, when I observed alone. The record has been kept by Mr. Gustavus A. Schuldt, principally, by Mrs. Thome, and, when the night was a six-hour or five-hour one, the last zone was also recorded by me. The scale is not quite distinct for my vision, and I have, in consequence ruled upon it shorter, $5'$, divisions in addition, which has greatly assisted in the ease and readiness of estimating the reading, and my eye is much rested, too, by looking out at the sky during rattles. The transits are for the moment of extinction of light by the scale, as nearly as possible. When several stars transit at the same moment, one tap records the common time, and an "also" accompanies the scale-readings, and they are indicated upon the record by a bracket, or simply by a vertical line. When two stars are too close to be observed separately, the scale-reading and magnitude are given for the brighter one, and it is marked "dpl." Nebulas are described as fully as the conditions will permit — apparent diameter, appearance and brightness. Our places for these agree closely, in the large majority of cases, with those given by Dr. Dreyer in his New General Catalogue, and we have found a number of new ones.

The chronographic times are read off and recorded as soon as possible after the observations, usually next day, and the identification of all the stars in the various Cordoba catalogues is then made. None of the objects whose positions are given in those publications, or in any other catalogue of positions that I have yet seen, except cases of palpable error, are missing in our work. The differential data furnished by all are used in the determination of the final constants of reduction for the middle of the zone. They are varied for beginning and end, and sometimes, slightly, with the scale-reading. The correction in declination, although determined for the middle of the zone, is afterward referred to the north limit, so that it is always a quantity additive directly to the scale-reading. Owing to the short duration of the zones, and the fact that the constants of reduction for each zone are deduced independently of all the others, the variation in constants for the beginning and end, and the extreme limits in declination are so small that the errors of observation would not be essentially increased by the assumption of a constant reduction. The final places are given to tenths of a second, and to tenths of a minute in declination. The arithmetical mean of the several estimates of magnitude is given to tenths, also.

From the following table, which gives a count by magnitudes of all objects observed at least twice in the first five degrees (22–26) of 0^h, it appears that our lower limit includes everything as far as 10.1, and that our usual reach upon a good night extends to about 10.3. There are 2038 stars in this region whose positions and magnitudes have been verified, and there are 600 more, of the lowest grade of brightness, with only one observation, and which are therefore only trustworthy as regards the magnitudes. These will not be further observed.

Count of DM. Stars, —22° to —26°, 0^h.

Mag.	By count		Per mil.	By regular progression		Mag.
Brighter than 7	24	24	0.012	24	24	
7.0	2		.000	1.5		
7.1	4		2	1.7		
7.2	4	21	2	2	10.7	$7\frac{1}{4}$
7.3	6		3	2.5		
7.4	5		2	3		

Mag.	By count		Per mil.	By regular progression		Mag.
Brighter than 7.5	4		2	3.5		
7.6	3		1	4.2		
7.7	7	28	3	5	25.7	7¾
7.8	10		5	6		
7.9	4		2	7		
8.0	14		7	8		
8.1	8		4	10		
8.2	11	62	5	12	61	8¼
8.3	17		8	14		
8.4	12		6	17		
8.5	32		16	20		
8.6	17		8	24		
8.7	26	142	13	29	147	8¾
8.8	25		12	34		
8.9	42		21	40		
9.0	49		24	48		
9.1	60		30	57		
9.2	58	348	29	67	347	9¼
9.3	96		47	80		
9.4	85		42	95		

Mag.	By count		Per mil.		By regular progression		Mag.
Brighter than 9.5	125		62		114		
9.6	161		79		136		
9.7	197	828	97		162	833	9¾
9.8	148		73		192		
9.9	197		.097		229		
10	585	585	0.286	10.0	273		
				10.1	325	598	
Sum		2038	1.000			2046	
Observed once		600		10.2	381		
				10.3	460	1389	10¼
				10.4	548		
Total		2638				3435	

In the Introduction to the *Bonner Sternverzeichniss*, Vol. VIII, pages 22–26, Prof. SCHÖNFELD has given the result of a count, for each four minutes of right-ascension and each degree of declination, of the stars observed by him for his Durchmusterung. The stars observed for the Cordoba Durchmusterung in the belt of —22° have been counted in the same manner, and in the table which follows the results obtained by each have been placed side by side for comparison of reach.

NUMBER OF STARS IN —22° DECLINATION AS OBSERVED AT BONN AND AT CORDOBA.

0h 0m	4m	8m	12m	16m	20m	24m	28m	32m	36m	40m	44m	48m	52m	56m	60m	Total	Ratio
Sch.	18	11	14	12	16	10	14	14	12	12	7	17	13	14	15	199	
Cord.	23	22	30	20	32	15	26	27	22	28	22	22	29	34	27	379	1.90
Ih																	
Sch.	11	10	6	11	10	9	7	9	11	11	9	10	14	14	16	158	
Cord.	27	16	22	23	24	22	15	15	20	19	21	21	26	21	24	316	2.00
IIh																	
Sch.	15	6	8	11	16	16	15	10	13	11	11	17	17	10	15	191	
Cord.	34	21	17	15	26	23	27	21	24	25	23	25	27	17	26	351	1.84
IIIh																	
Sch.	12	11	10	12	13	10	13	10	16	19	15	14	16	14	15	200	
Cord.	30	24	30	28	17	21	26	22	27	24	35	33	31	19	31	398	1.99
IVh																	
Sch.	18	13	22	10	12	17	11	18	18	25	17	17	19	16	26	259	
Cord.	35	25	40	26	39	36	31	31	32	48	36	32	41	36	48	536	2.07
Vh																	
Sch.	24	19	17	22	17	22	21	21	19	30	18	15	21	18	17	305	
Cord.	41	38	44	49	41	46	48	41	45	53	56	47	53	65	63	730	2.39
VIh																	
Sch.	19	19	17	25	15	26	19	28	15	28	30	30	40	45	32	388	
Cord.	56	71	53	70	72	64	80	79	85	85	99	106	109	110	106	1245	3.21
VIIh																	
Sch.	31	31	35	38	32	33	32	28	28	28	29	25	27	27	26	450	
Cord.	108	108	102	96	97	86	106	140	144	137	121	106	120	110	102	1683	3.74
VIIIh																	
Sch.	23	23	25	23	24	31	22	17	28	23	25	25	15	22	21	347	
Cord.	103	103	105	95	94	90	96	91	96	71	73	62	83	57	49	1268	3.65
IXh																	
Sch.	16	25	21	30	24	13	26	20	21	23	23	20	26	26	23	334	
Cord.	53	75	75	68	82	65	73	72	63	64	74	63	69	74	61	1031	3.09

Xh	0m	4m	8m	12m	16m	20m	24m	28m	32m	36m	40m	44m	48m	52m	56m	60m	Total	Ratio
Sch.	23	21	15	18	11	11	20	19	19	17	9	22	12	20	12		219	
Cord.	59	57	66	64	54	59	58	48	59	47	44	42	37	40	44		775	3.11
XIh																		
Sch.	14	8	9	17	16	10	20	14	14	12	17	10	16	12	22		211	
Cord.	47	39	41	48	46	35	46	13	47	42	27	35	39	35	33		613	2.90
XIIh																		
Sch.	11	14	23	21	11	14	17	10	16	15	8	21	10	6	16		216	
Cord.	25	28	35	46	23	30	39	29	40	36	22	32	24	28	31		468	2.17
XIIIh																		
Sch.	19	13	22	16	17	20	12	16	9	10	12	9	21	11	12		219	
Cord.	30	33	35	46	37	31	35	36	30	39	38	31	42	29	40		532	2.43
XIVh																		
Sch.	17	12	12	19	6	11	11	11	11	12	7	12	11	14	11		177	
Cord.	44	42	20	34	31	35	34	43	38	37	37	34	37	36	44		546	3.09
XVh																		
Sch.	8	13	10	14	12	11	14	17	12	14	15	13	12	9	17		191	
Cord.	28	38	28	31	37	33	37	41	35	35	35	29	31	35	46		519	2.72
XVIh																		
Sch.	21	17	22	10	4	5	3	8	16	17	17	14	13	11	13		191	
Cord.	43	49	50	23	12	11	11	16	35	29	13	31	51	31	41		479	2.51
XVIIh																		
Sch.	15	10	14	19	6	13	16	12	16	24	13	19	28	58	32		295	
Cord.	16	51	36	47	19	32	41	41	36	39	49	58	44	90	91		723	2.45
XVIIIh																		
Sch.	30	35	36	29	27	29	36	22	18	23	32	25	20	22	24		408	
Cord.	97	89	68	81	65	54	81	61	52	56	63	70	75	57	68		1037	2.48
XIXh																		
Sch.	23	24	28	32	24	19	27	22	23	30	22	19	19	24	17		353	
Cord.	59	68	67	65	68	57	60	50	45	48	67	64	38	63	40		859	2.43
XXh																		
Sch.	20	18	15	26	15	24	23	13	19	23	15	18	14	15	14		272	
Cord.	48	36	39	54	45	49	65	51	57	58	40	38	42	41	36		699	2.57
XXIh																		
Sch.	11	15	27	12	13	15	17	16	15	12	15	12	16	13	14		223	
Cord.	43	39	40	36	37	30	42	34	35	27	41	37	40	33	26		540	2.42
XXIIh																		
Sch.	17	17	18	15	13	15	14	17	23	15	8	17	17	8	18		232	
Cord.	37	37	25	27	31	30	28	32	34	29	30	34	29	18	29		450	1.94
XXIIIh																		
Sch.	18	14	10	8	15	6	14	17	9	14	14	17	15	15	11		197	
Cord.	32	24	30	22	22	21	22	31	24	25	27	25	31	20	20		376	1.91
																Sch.	6265	
																Cord.	16550	2.64

To test the correctness and general relation of our adopted magnitudes, comparisons have been made, on p. 109, with Schönfeld's SDM. and the Cordoba Zone-Catalogues. In the comparison with Schönfeld, his determinations and the Cordoba ones have been used alternately as standards. The comparisons with the Zone-Catalogue have usually extended over ten degrees.

Finally, in the table on p. 110 is given the probable error of our adopted positions as deduced from the differences between these and those given in the Argentine General Catalogue, Oeltzen's Argelander, Cordoba Zone-Catalogues and Schönfeld's SDM. For the first three, the positions given have been accepted as being without sensible error in comparison with our determinations, and for Schönfeld's the reduction was made upon the assumption that his and our determinations are effected by an equal error. This is not quite true, and our positions would undoubtedly have been much improved if we, too, had used an illuminated reticule. But as that implied a sacrifice of nearly all the objects fainter than $9\frac{1}{2}^{\text{M}}$, I preferred to adhere to dark field and longer reach. It must be remembered, also, that the constants of reduction were determined from the brighter stars at the moment of extinction, and that they are not quite correct for the mass of faint stars, as these latter are extinguished or lost, in the vicinity of the transit line, earlier than the bright stars, although really having a greater right-ascension.

COMPARISON OF MAGNITUDES WITH SCHÖNFELD'S SDM.

Mag.		$7^M - 7^M.4$	$7^M.5 - 7^M.9$	$8^M.0 - 8^M.4$	$8^M.5 - 8^M.9$	$9^M.0 - 9^M.4$	$9^M.5 - 10^M$	10^M
0^h	Sch. standard	7.10 7.25	7.62 7.56	8.17 8.19	8.61 8.67	9.18 9.31	9.65 9.64	10 9.85
	C. standard	7.30 7.28	7.90 7.70	8.20 8.28	8.55 8.70	9.16 9.20	9.69 9.70	9.94 10
	No. comp. Sch.	2	5	15	12	49	68	17
	No. comp. C.	4	6	8	14	41	76	12
I^h	Sch. standard	7.00 6.90	7.83 7.87	8.13 8.17	8.67 8.72	9.21 9.16	9.66 9.58	10 9.80
	C. standard		7.70 7.90	8.23 8.27	8.71 8.82	9.19 9.26	9.65 9.70	9.81 10
	No. comp. Sch.	2	4	11	15	44	39	17
	No. comp. C.		3	12	23	33	51	7
III^h	Sch. standard			8.22 8.28	8.69 8.78	9.24 9.31	9.65 9.72	10 9.96
	C. standard			8.40 8.22	8.75 8.72	9.16 9.25	9.56 9.69	9.81 10
	No. comp. Sch.			10	28	65	62	10
	No. comp. C.			10	24	51	71	18
V^h	Sch. standard		7.60 7.50	8.12 8.07	8.72 8.71	9.21 9.20	9.63 9.55	10 9.75
	C. standard							9.80 10
	No. comp. Sch.		1	16	32	107	119	24
	No. comp. C.							65
VII^h	Sch. standard	7.20 7.00	7.68 7.62	8.18 8.32	8.72 8.89	9.19 9.29	9.66 9.61	10 9.78
	C. standard							9.82 10
	No. comp. Sch.	2	6	12	35	158	200	34
	No. comp. C.							28
Mean Sch. — C.								
	0^h	—0.06	+0.13	—0.05	—0.08	—0.08	0.00	+0.05
	I	+ .10	+ .12	00	+ .03	+ .06	+ .06	.00
	III			+ .06	— .03	— .08	— .10	— .08
	V		+ .10	+ .05	+ .01	+ .01	+ .08	+ .03
	VII	+0.20	+0.06	—0.14	—0.17	—0.10	+0.05	+0.02

COMPARISON OF MAGNITUDES WITH THE CORDOBA ZONE-CATALOGUES

Zone Mag.		7	7¼	7½	7¾	8	8¼	8½	8¾	9	9¼	9½	9¾	10
II^h	Cord. DM.	7.10	7.29	7.40	7.66	7.92	8.18	8.51	8.57	8.82	9.01	9.02	–	9.20
	No. comp.	5	12	21	15	11	23	67	41	95	21	22		3
III^h	Cord. DM.	7.09	7.25	7.43	7.78	8.05	8.23	8.19	8 66	8.86	8.91	8.85	–	8.83
	No. comp.	12	11	20	16	31	32	65	15	100	15	11		3
IV^h	Cord. DM.	7.19	7.21	7.32	7.51	7.86	8.17	8.40	8.57	8.75	8.95	9.09	–	9.11
	No. comp.	10	9	18	20	39	44	66	60	148	23	71		7
V^h	Cord. DM.	7.06	7.34	7.55	7.71	7.92	8.21	8.38	8.54	8.85	8.87	9.11	9.10	9.31
	No. comp.	14	9	15	17	39	38	93	50	202	43	114	2	21
VII^h	Cord. DM.	7.21	7.67	7.66	7.71	8.05	8.07	8.54	8.77	8.97	9.08	9.27	–	9.34
	No. comp.	21	3	19	7	46	27	121	28	227	22	171		22
Mean, Z.C.—D.M.														
	II	—0.10	—0.01	+0.10	+0.09	+0.08	+0.07	—0.01	+0.18	+0.18	+0.21	+0.48		+0.80
	III	.09	.00	+ .07	— .03	— .05	+ .02	+ .01	+ .09	+ .14	+ .34	+ .65		+1.17
	IV	.19	+ .01	+ .18	+ .24	+ .11	+ .08	+ .10	+ .18	+ .25	+ .30	+ .41		+ .86
	V	.06	— .09	— .05	+ .04	+ .08	+ .04	+ .12	+ .21	+ .15	+ .38	+ .36	+0.65	+ .69
	VII	—0.21	—0.42	—0.16	+0.04	—0.05	+0.18	—0.01	—0.02	+0.03	+0.17	+0.23		+0.66

Determination of the Probable Error of Adopted Positions.

Catalogue		No. Comp.	Width	P.e. of Diff.		P.e. of Positions	
			°	s	'	s	'
0h	Sch. DM.	199	1	±0.61	±0.35	±0.41	±0.23
Ih	Sch. DM.	188	1	.67	.45	.45	.22
	A.G.C.	37	10	.34	.17	.34	.17
IIh	Sch. DM.	191	1	.59	.40	.40	.26
	A.G.C.	35	10	.44	.26	.44	.26
	Oe. Arg.	25	5	.45	.25	.45	.25
IIIh	Sch. DM.	200	1	.62	.34	.44	.24
	A.G.C.	42	10	.44	.21	.44	.21
	Oe. Arg.	57	8	±0.44	±0.26	±0.44	±0.26
IVh	Sch. DM.	259	1	±0.60	±0.35	±0.42	±0.25
	A.G.C.	35	10	.43	.21	.43	.21
	Oe. Arg.	50	8	.50	.25	.50	.25
Vh	Sch. DM.	305	1	.56	.33	.39	.23
	A.G.C.	37	10	.45	.23	.45	.23
	Oe. Arg.	51	8	.43	.24	.43	.24
	C.Z.C.	134	10	.40	.22	.40	.22
VIIh	Sch. DM.	150	1	.56	.33	.39	.23
	A.G.C.	43	10	±0.40	±0.22	±0.40	±0.22
						±0.42	±0.23

Cordoba, 1890 *October* 10.

FILAR-MICROMETER OBSERVATIONS OF COMET *e* 1890 (*ZONA, Nov. 15*),

MADE WITH THE 12-INCH EQUATORIAL OF THE LICK OBSERVATORY,

BY E. E. BARNARD.

1890 Mt. Hamilton M.T.	*	No. Comp.	☄ — *		☄'s apparent		log $p\Delta$	
			$\Delta\alpha$	$\Delta\delta$	α	δ	for α	for δ
h m s			m s	' "	h m s	° ' "		
Nov. 17 8 17 22	1	4 , 6*	−0 0.58	−11 9.4	5 23 10.53	+33 55 38.8	n9.745	0.566
18 7 10 19	2	18 , 6	−0 33.61	+ 2 37.5	5 17 43.68	+34 7 47.3	n9.754	0.669
19 7 22 6	3	16 , 6	+0 11.86	+ 2 10.8	5 11 52.78	+34 19 32.4	n9.756	0.635

Mean Places for 1890.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	m s		° ' "		
1	5 23 7.73	+3.38	+34 6 44.4	+3.8	Lal. 10245
2	5 18 13.88	+3.41	+34 5 6.4	+3.7	Weisse's Bessel, 5h 439
3	5 11 37.48	+3.44	+34 17 18.1	+3.5	Compared with Bonn VI, 34° 996

* $\Delta\alpha$ measured directly with the micrometer.

The comet is round, gradually brighter in the middle, with no definite nucleus. It is about 12M.

Star 3 — Bonn 34° 996 —0m 20s.49 (18), —4' 10".4 (3)

The star DM. 34° 995 was compared with star 3.

DM. 34° 995, $\alpha = 5^h\ 11^m\ 58^s.31$, $\delta = +34° 26' 57''.0$ (1890.0)

DM. 34° 995, — *3 +0m 20s.83 (12), +9' 38".9 (3)

RING-MICROMETER OBSERVATIONS OF COMET *e* 1890 (*ZONA*),

MADE WITH THE RUTHERFURD (13-INCH) EQUATORIAL OF COLUMBIA COLLEGE OBSERVATORY,

BY J. K. REES AND HAROLD JACOBY.

1890 Col. College M.T.	*	No. Comp.	☄ — *		☄'s apparent		log $p\Delta$		Obs.
			$\Delta\alpha$	$\Delta\delta$	α	δ	for α	for δ	
h m s			m s	' "	h m s	° ' "			
Nov. 18 10 25 37	1	1	−0 35.59	+2 44.9	5 17 41.72	+34 7 54.5	n9.582	0.320	Jac.
18 11 7 0	1	5	−0 14.96	+3 2.4	5 17 32.35	+34 8 12.0	n9.486	0.218	Rees
20 11 32 20	2	4	−0 19.88	−4 56.4	5 5 49.49	+34 30 56.5	n9.331	0.094	Jac.
20 11 42 4	2	6	−0 22.85	−5 8.1	5 5 46.52	+34 30 44.8	n9.285	0.072	Rees

Mean Places for 1890.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ' "	"	
1	5 18 13.71	+3.59	+34 5 5.7	+3.8	Paris 6222
2	5 6 5.72	+3.65	+34 35 47.9	+5.0	Weisse's Bessel V, 65

ON THE REOBSERVATIONS OF COMET 1889 V *(BROOKS, July 6, 1889)*,

MADE WITH THE 36-INCH EQUATORIAL OF THE LICK OBSERVATORY,

BY E. E. BARNARD.

About six weeks ago, Dr. BERBERICH kindly sent me an ephemeris of Comet 1889 V (BROOKS, July 6, 1889), in hopes that the comet might still be observable with the great telescope on Mt. Hamilton. The ephemeris was computed for every other day, and extended from Oct. 11, 1890, to Jan. 7, 1891. Since then I have searched for the comet with the 36-inch at every favorable opportunity, but up to Nov. 21, no trace of it could be found. I still had strong hopes, however, that the comet might yet be seen.

The night of Nov. 21, after moonset, proving to be very fine, I determined to make one last effort to refind the comet. I began a slow and careful examination of the sky near the ephemeris place, and after fully an hour's search, finally found a most excessively faint and difficult object. It was about 10″ in diameter, excessively diluted, and no brighter in the middle. As it was impossible to see the object steadily enough to put the wires on it, even by oblique vision, I mentally fixed its position with reference to small stars near it, and then bisected the place where I could occasionally see it; this could be done quite closely, as the observations in both coordinates were made direct with the micrometer — the field being only 5′ in diameter. The observations were referred to a 13^M star, which was afterwards compared with a 10^M star, and this in turn was referred to W.B. 8^h 1417. The following morning the place was again examined, and the object was missing. It was, however, finally found again 1′ or 2′ n.f. the original position. Its place was again referred to the 13^M star. The night of the 23d proved cloudy, and since then the moon has interfered.

The object is undoubtedly the sought for comet.

The observations were made nearly in the zenith, with a pure sky and first-class seeing. Under these same conditions the comet can be observed again when the moon withdraws, but unless these conditions prevail in the strictest sense, it is hopeless to see the object again. From its faintness, it is impossible to observe its place closer than 1^s or 2^s.

The comet is now the faintest and most difficult object that I have ever seen in the heavens, and from its present appearance no other telescope in existence can possibly show a trace of it.

The importance of any observations of this remarkable object, now, eight months after it had been given up as beyond reach, will readily be understood when we consider the possibility of its being the comet of LEXELL, the identity with which such observations will perhaps alone prove or disprove.

During these observations the comet's distance from the earth was 3.09 and 3.55 from the sun; and its light 0.41 that of the last observations in March. It is increasing in brightness slowly, and the light will be 0.45 on Jan. 7, 1891.

Following are the two filar-micrometer observations of Nov. 21 and 22:

1890 Mt. Hamilton M.T.	☄ — * $\Delta\alpha$	☄ — * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	$\log p\Delta$ for α	$\log p\Delta$ for δ
	m s	′ ″	h m s	° ′ ″		
Nov. 21 16 18 48	−0 1.81	−1 44.1	9 0 34.16	+24 13 10.1	*n*8.851	0.303
22 16 47 44	+0 3.49	−0 12.2	9 0 39.49	+24 14 41.9	7.954	0.294

Mean Place for 1890.0 of Comparison-Star.

α	Red. to app. place	δ	Red. to app. place
h m s	s	° ′ ″	″
9 0 53.60	−2.37 −2.40	+24 15 4.5	−10.3 −10.4

	$\Delta\alpha$	$\Delta\delta$
* 13^M — * 10^M =	$+0^m\ 17^s.20$	$+1'\ 16''.5.$
* 10^M — W.B. 8^h 1417 =	$+0^m\ 33^s.77$	$+2'\ 52''.2.$

These observations given for the 10^M star (1890.0).

$\alpha = 9^h\ 0^m\ 16^s.40, \qquad \delta = +24°\ 13'\ 48''.0.$

EPHEMERIS OF COMET 1889 V.

BY WILLIAM BELLAMY.

This ephemeris is computed from the elements given by Mr. CHARLES L. POOR in No. 228 of the *A.J.*, and should give the comet's place with considerable precision. The theoretical brightness of the comet is about three magnitudes fainter than at discovery; so that it is probably well within reach of several of the larger telescopes. As it is extremely desirable to determine the orbit with the greatest possible precision, in order to fix the exact conditions of its approach to *Jupiter* in 1886, and its previous path, any observations that can be now obtained will be of the utmost value.

Gr. M.T.	App. α	App. δ	log Δ	log r
1890	h m s	° ′ ″		
Dec. 1.5	9 0 35.0	+24 29 46	0.47607	0.55339
2.5	0 27.9	31 58		
3.5	0 19.4	34 16		
4.5	9 0 9.5	36 39	.47227	
5.5	8 59 58.2	39 6		
6.5	59 45.6	41 37		
7.5	59 31.6	44 11	.46863	.55653
8.5	59 16.4	46 49		
9.5	58 59.8	49 32		
10.5	58 41.9	52 20	.46517	
11.5	58 22.7	55 11		
12.5	58 2.2	24 58 5		
13.5	57 40.5	25 1 3	.46192	.55962
14.5	57 17.4	4 4		
15.5	56 53.1	7 8		
16.5	56 27.5	10 15	.45891	
17.5	56 0.7	13 24		
18.5	55 32.7	16 37		
19.5	55 3.5	19 53	.45616	.56267
20.5	54 33.1	23 11		
21.5	54 2.5	26 31		
22.5	53 28.6	29 52	.45369	
Jan. 3.5	45 33.5	26 11 18	.44714	
4.5	44 48.1	14 44		
5.5	44 1.9	18 9		
6.5	8 43 15.0	+26 21 34	0.44644	0.57158
1891	h m s	° ′ ″		
Jan. 7.5	8 42 47.3	+26 24 57		
8.5	41 38.9	28 18		
9.5	40 49.9	31 36	0.44615	
10.5	40 0.4	34 52		
11.5	39 10.4	38 6		
12.5	38 19.9	41 17	.44629	0.57447
13.5	37 29.0	44 25		
14.5	36 37.7	47 30		
15.5	35 46.1	50 32	.44685	
16.5	34 54.2	53 31		
17.5	34 2.1	56 26		
18.5	33 9.9	26 59 17	.44785	.57732
19.5	32 17.5	27 2 4		
30.5	22 44.4	27 40	.45615	.58290
31.5	21 53.8	29 30		
Feb. 1.5	21 3.7	31 14		
2.5	20 14.0	32 53	.45926	
3.5	19 24.8	34 26		
4.5	18 36.2	35 54		
5.5	17 48.3	37 17	.46275	.58563
6.5	17 1.0	38 84		
7.5	16 14.4	39 45		
8.5	15 28.4	40 51	.46661	
9.5	14 43.2	41 51		
10.5	13 58.8	42 46		
11.5	8 13 15.2	+27 43 36	0.47083	0.58832

This ephemeris was unavoidably postponed from no. 229. Its correction for Nov. 22 was, according to Barnard's observations, —4^s.50 and +30″.7.—G.

COMET *e* 1890 (*ZONA*).

From a Letter of Rev. GEORGE M. SEARLE.

I have computed another orbit of the comet from observations at Palermo, Nov. 15, using the Cambridge observation of Nov. 19. The elements are as follows:

$$T = 1890 \text{ Aug. } 12.3978 \text{ Gr. M.T.}$$

$$\left.\begin{aligned} \Omega &= 85^\circ\ 40'\ 18'' \\ i &= 154\ \ 42\ \ 56 \\ \omega &= 334\ \ 38\ \ \ 8 \end{aligned}\right\} 1890.0$$

$$\log q = 0.320952$$

The rectangular coordinates for the equator are:

$$x = 9.956540\ r \sin(v + 339^\circ\ 25'\ 14'')$$
$$y = 9.974915\ r \sin(v + \ 78\ \ 54\ \ \ 7\ )$$
$$z = 9.731562\ r \sin(v + \ 22\ \ \ 3\ \ 26\ )$$

The place given by these for Dec. 6.5 differs only by —23^s and —8″ from the ephemeris previously computed.

COMET *f* 1890.

A dispatch from Dr. Krueger announces the rediscovery of this comet, and the position,

Dec. 4.2512 Greenw. M.T. $\alpha = 5^h\ 15^m\ 20^s.0$, $\delta = +37^\circ\ 22'\ 35''$. Daily motion, —56^s in α. and 12′ northward.

It is circular, less than 1′ in diameter, not brighter than 11^M, with well-defined nucleus and no tail.

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ON THE THEORY OF THE MOON'S MOTION,

BY JOHN N. STOCKWELL.

1. In number 226 of this *Journal* Prof. G. W. Hill has criticised my computation of the secular motion of the moon's perigee, which appeared in no. 220 of the *Journal*. His criticism may properly be divided into two parts. In the first part he states that the differential equation of the motion of the perigee should contain no instantaneous element; and in the second he insists that the eccentricity of the earth's orbit should be regarded as variable in the development of the differential equations of the moon's motion.

2. I freely admit the correctness of the first point of his criticism; but as the effect of this oversight can only be determined by means of a careful calculation, no further notice will be taken of it here. As soon as I have leisure I will investigate its effect on the secular motion of the perigee, and the result of the investigation will then be given to astronomers.

3. In regard to the second point, I am unable to agree with him, at least in so far as its calculated effect on the moon's motion is concerned. I believe this point was first raised by Prof. J. C. Adams of Cambridge, England, one of the theoretical discoverers of the planet *Neptune*, in a memoir on the secular acceleration of the moon's motion, which appeared in the *Philosophical Transactions of the Royal Society of London* for the year 1853. The same idea was afterwards more fully developed by Prof. Adams, and also by M. Delaunay of France. Later still several other mathematicians have given more or less extensive developments of the same hypothesis. And last of all it is proper to mention an investigation of the same subject by Prof. G. W. Hill in *The Analyst* for July 1878. All these investigators arrive, by essentially different methods of investigation, at identically the same result, as to the effect on the moon's motion. But in all these investigations it seems to me that a most important element of the problem has been overlooked, namely, the fact that the assumed law of variation of the eccentricity is so radically different from the actual law that the calculated effects do not apply to the case in nature. The calculated effects of a law of disturbance cannot well be more correct than the law itself, no matter how skilful the calculator may be.

4. We should hardly regard a mathematical work as possessing a high degree of excellence, if its calculations were based on the assumption that the sine of an arc is either equal to, or proportional to, the length of the arc itself; and yet the assumption of Prof. Adams, in regard to the law of the variation of the eccentricity of the earth's orbit, is in no sense more correct. The theory of the secular variations of the motions of the moon and planets contemplates the consideration of forces whose action is not limited to a period of a few years or centuries, but to those which have the whole extent of time to work in, thus embracing all past and future ages. The supposition of a uniform variation of the eccentricity of the earth's orbit therefore differs more widely from the truth than would the assumption of no variation at all when long periods of time are to be considered in the calculation.

5. Prof. Adams in the opening paragraph of his memoir very truthfully says: — "In treating a great problem of approximation, such as that presented to us by the investigation of the moon's motion, experience shows that nothing is more easy than to neglect, as insignificant, considerations which ultimately prove to be of the greatest importance." And yet, notwithstanding the caution inculcated in the preceding paragraph, he seems to have overlooked a most important consideration, as I shall presently show.

After giving the different equations which determine the moon's *radius vector* and the *time*, in functions of the moon's true longitude as the independent variable, Prof. Adams says: "In the solution usually given of these equations, u is expressed by means of a constant part and a series involving *cosines* of angles composed of multiples of $2v - 2mv$, $cv - \omega$, and $c'mv - \omega'$; also t is expressed by a part proportional to v and a series involving *sines* of the same angles; the coefficients of the periodic terms being functions of m, e and e'. Now if e' be a constant quantity, this is the true form of the solution; but if e' be variable, it is impossible to satisfy the differential equations without adding to the expression for u a series of small supplementary terms depending on the *sines* of the angles whose cosines are already involved in it, and to that for t, similar terms depending on the *cosines* of the same angles, the coefficients of these new terms involving $\frac{de'}{dt}$ as a factor."

It is not necessary to enter into a detailed discussion of Prof. ADAMS's memoir in this place, as my only object is to show that the results obtained by him arise from the particular *form* assumed for the expression of the factor $\frac{de'}{dt'}$

6. The solution of the differential equation which determines the radius vector gives rise to the following terms, which I have denoted by F; namely,

$$(1) \qquad F = -\frac{3m^2}{a_1}\int dv \left\{ (1-\tfrac{5}{2}e'^2)\sin(2v-2mv) + \tfrac{7}{2}e'\sin(2v-2mv-c'mv) - \tfrac{1}{2}e'\sin(2v-2mv+c'mv) \right\}$$

Integrating this equation by parts, supposing e' to be variable, gives, by neglecting m in the divisors introduced by the integrations,

$$(2)\left\{\begin{array}{l} F = \left[F' = \tfrac{3}{2}\frac{m^2}{a_1}(1-\tfrac{5}{2}e'^2)\cos(2v-2mv) + \tfrac{21}{4}\frac{m^2}{a_1}e'\cos(2v-2mv-c'mv) - \tfrac{3}{4}\frac{m^2}{a_1}e'\cos(2v-2mv+c'mv)\right] \\ \quad + \left[F'' = \tfrac{15}{2}\frac{m^2}{a_1}\int dv\frac{e'de'}{dv}\cos(2v-2mv) - \tfrac{21}{4}\frac{m^2}{a_1}\int dv\frac{de'}{dv}\cos(2v-2mv-c'mv) + \tfrac{3}{4}\frac{m^2}{a_1}\int dv\frac{de'}{dv}\cos(2v-2mv+c'mv)\right] \end{array}\right.$$

In this equation F' denotes the terms given by the ordinary theory, and F'' denotes the new terms introduced by Prof. ADAMS.

Equation (2) contains the factor $\frac{de'}{dv}$; and in order to find its value Prof. ADAMS assumes that $\frac{de'}{dt} = \alpha =$ a constant.

(3) And since $$\frac{de'}{dv} = \frac{de'}{dt}\cdot\frac{dt}{dv} = \alpha\frac{dt}{dv},$$ and

$$(4) \qquad \left\{\frac{dt}{dv} = 1 - \tfrac{11}{4}m^2\cos(2v-2mv) - \tfrac{77}{8}m^2e'\cos(2v-2mv-c'mv) + \tfrac{11}{8}m^2e'\cos(2v-2mv+c'mv)\right\}$$

we shall have

$$(5) \qquad \frac{de'}{dv} = \alpha\left\{1 - \tfrac{11}{4}m^2\cos(2v-2mv) - \tfrac{77}{8}m^2e'\cos(2v-2mv-c'mv) + \tfrac{11}{8}m^2e'\cos(2v-2m'v+c'mv)\right\}$$

This gives by integration

$$(6) \qquad e' = e'_0 + \alpha v - \tfrac{11}{8}m^2\alpha\sin(2v-2mv) - \tfrac{77}{16}m^2e'\alpha\sin(2v-2mv-c'mv) + \tfrac{11}{16}m^2e'\alpha\sin(2v-2mv+c'mv)$$

e'_0 being the constant to complete the integral.

We may remark in this place that Prof. HILL assumes that $\frac{de'^2}{dt}$ is a constant quantity, which is incompatible with the assumption of Prof. ADAMS. For $\frac{de'^2}{dt} = 2e'\frac{de'}{dt}$; (7) and if $\frac{de'}{dt}$ is constant, it follows that e' must itself be constant, which would give $\frac{de'}{dt} = 0$, and equation (6) would be reduced to its first term.

The new terms found by Prof. ADAMS arise from the terms of equation (2) which remain under the sign of integration, and which I have denoted by F''. If we substitute in it the values of e' and $\frac{de'}{dv}$ which are given by equations (5) and (6), we shall get

$$(8)\left\{\begin{array}{l} F'' = \tfrac{15}{4}\frac{m^2}{a_1}e'_0\,\alpha\sin(2v-2mv) + \tfrac{99}{16}\frac{m^3}{a_1}\alpha\sin c'mv - \tfrac{21}{8}\frac{m^2}{a_1}\alpha\sin(2v-2mv-c'mv) + \tfrac{3}{8}\frac{m^2}{a_1}\alpha\sin(2v-2mv+c'mv) \\ \quad + \tfrac{495}{64}\frac{m^4}{a_1}\left\{\int 2e'_0\,\alpha dv = 2e'_0\alpha v\right\} \end{array}\right.$$

The first four terms of this equation are a part of the supplementary terms found by Prof. ADAMS; and if we add $\frac{495}{64}\frac{m^4}{a_1}e_0'^2$ to the last term it will become

$$(9) \qquad \tfrac{495}{64}\frac{m^4}{a_1}\left\{e_0'^2 + 2e'_0\alpha v\right\} = \tfrac{495}{64}\frac{m^4}{a_1}e'^2$$

which is the same as found by Prof. ADAMS. But we have no right to add a constant to the integral of $2e'_0\alpha dv$ since the term ought to vanish if $\alpha = 0$.

We thus see how the terms found by Prof. ADAMS arise from the development of his hypothesis in regard to the variation of the solar eccentricity; and I shall now show that such terms do not arise if the true law of the variation be used instead of the assumed law.

7. In the first place we observe that the differential equation of the eccentricity contains no constant term, but is composed of a series of terms depending on the *sines* of the angles which determine the configuration of the different bodies of the system, or of their elements. This fact may be shown either by developing the differential equation or by a reference to authors on mathematical astronomy who have treated of the subject.

The correct expression for $\frac{de'}{dt}$ would therefore contain no constant term, but would be composed of a series of terms of the form

$$\frac{de'}{dt} = \alpha \sin \beta t \tag{10}$$

in which α and β are constant quantities. Confining our attention to a single term whose form will be the same if we change t to v, we may write

$$\frac{de'}{dt} = \alpha \sin \beta v \tag{11}$$

in which α and β are very small constant quantities in the secular terms; and then equation (3) will give

$$\begin{aligned}\frac{de'}{dv} = {} & \alpha \sin \beta v - \tfrac{11}{8}\, m^2\alpha \left\{ \sin(2v-2mv+\beta v - \sin(2v-2mv-\beta v) \right\} \\ & - \tfrac{77}{16}\, m^2e'\alpha \{\sin(2v-2mv-c'mv+\beta v) - \sin(2v-2mv-\beta v)\} \\ & + \tfrac{11}{16}\, m^2e'\alpha \{\sin(2v-2mv+c'mv+\beta v) - \sin(2v-2mv+c'mv-\beta v)\}\end{aligned} \tag{12}$$

This equation gives by integration, neglecting m and β in the divisors, except for the first term,

$$\begin{aligned}e' = e'_0 & - \frac{\alpha}{\beta} \cos \beta v + \tfrac{11}{16}\, m^2\alpha \left\{ \cos(2v-2mv+\beta v) - \cos(2v-2mv-\beta v) \right\} \\ & + \tfrac{77}{32}\, m^2e'\alpha \{\cos(2v-2mv-c'mv+\beta v) - \cos(2v-2mv-c'mv-\beta v)\} \\ & - \tfrac{11}{32}\, m^2e'\alpha \{\cos(2v-2mv+c'mv+\beta v) - \cos(2v-2mv+c'mv-\beta v)\}\end{aligned} \tag{13}$$

If we now substitute these values of e' and $\frac{de'}{dv}$ in the value of F'' we shall get

$$\begin{aligned}F'' = {} & \tfrac{15}{8} \frac{m^2}{a_1} e'_0\alpha \left\{ \cos(2v-2mv-\beta v) - \cos(2v-2mv+\beta v) \right\} \\ & + \tfrac{21}{16} \frac{m^2}{a_1} \alpha \{\cos(2v-2mv-c'mv-\beta v) - \cos(2v-2mv-c'mv+\beta v)\} \\ & + \tfrac{3}{16} \frac{m^2}{a_1} \alpha \left\{ \cos(2v-2mv+c'mv-\beta v) - \cos(2v-2mv+c'mv+\beta v) \right\} \\ & + \tfrac{99}{32} \frac{m^4}{a_1} \left\{ \frac{\alpha}{c'm-\beta} \cos(c'mv-\beta v) - \frac{\alpha}{c'm+\beta} \cos(c'mv+\beta v) \right\} \\ & - \tfrac{495}{32} \frac{m^4}{a_1} e'_0 \frac{\alpha}{\beta} \cos \beta v\end{aligned} \tag{14}$$

This equation contains no terms depending on the *sines* of the angles given in equation (1), but it contains the *cosines* of the same angles increase by the secular term βv. Moreover, if we add the quantity $\frac{495}{64} \frac{m^4}{a_1} e'^2_0$ the last term will reduce to

$$\left\{ \tfrac{495}{64} \frac{m^4}{a_1} \left\{ e'^2_0 - 2e'_0 \frac{\alpha}{\beta} \cos \beta v \right\} = \tfrac{495}{64} \frac{m^4}{a_1} e'^2 \right. \tag{15}$$

being the same as equation (9). But as before stated, no constant should be added, since the term ought to disappear in case $\alpha = 0$.

We thus see that the supplementary terms found by Prof. Adams do not appear when the correct form for the variation of the eccentricity is employed in the investigation. Neither does the nonperiodic term appear unless we add a constant quantity, which is not required in the solution.

8. But this is not all; for in the integration of differential functions by parts, it is necessary that each of the two parts should be a function of the same independent variable. Now the eccentricity of the earth's orbit is certainly not a function of the moon's longitude. Its secular variation must therefore be independent of the same quantity, and we shall therefore have $\frac{de'}{dv} = 0$, and consequently all the terms which we have found, depending on that quantity ought to be identically equal to nothing. Of course this would not be true in so far as the eccentricity is affected by the moon itself; but the effect of that cause on the solar eccentricity has never been considered in the theories of the moon's motion.

Cleveland, Ohio, 1890 *Dec.* 3.

LIGHT-VARIATIONS OF *S PERSEI* AND *T ARIETIS*, BETWEEN THE YEARS 1883 AND 1888.

BY JOHN G. HAGEN, S.J.

Out of a series of observations of variable stars, made with a 3-inch glass, from 1883 until 1888, I have selected two stars whose elements seem to be so uncertain that a prediction of phases for the convenience of observers has been almost impossible.

The variability of the stars *S Persei* and *T Arietis* was discovered in 1873 and 1870 respectively, but except the observations published by Prof. Schönfeld in the *Astronomische Nachrichten*, Vols. 83 and 87 (1874 and 1876), no others were recorded until 1883 (see *Annals of Harvard College Observatory*, vol. 18, pp. 222,3), when my own series commenced.

This latter is not quite continuous, as my observations were usually made between 8 and 10 o'clock, or about 15^h Greenwich time. Still the branches of the light-curves, as observed every year, when plotted on a strip of paper, show the general course of variation in such manner that no doubt can arise as to the number of maxima and minima during those five years. *S Persei*, in particular, could be followed almost throughout the whole year, and the time of its invisibility was frequently recorded, a fact which proved very important in the reductions.

I. *S Persei.* (R.A. = 2^h 16^m).

The following table gives the general course of the light-variation of this star, as represented by my observations:

Table I.

1883	Autumn	Disappearance
1884	Spring	Minimum
"	Autumn	Reappearance
1885	Spring	*Maximum*
"	Autumn	Disappearance
1886	Summer	Minimum
"	Autumn	Reappearance
1887	Summer	*Maximum*
1888	Spring	Disappearance
"	Summer	Minimum

For the determination of period and epoch the only available phases were the two maxima of 1885 and 1887, the minima being beyond the reach of my instrument. The light-curves were first drawn separately, and the epochs determined in the usual way by bisecting the abscissas intercepted within each curve. The approximate results are, respectively, 1885 March 15 and 1887 July 7, with a plausible error of one or two weeks for each maximum.

To attain greater accuracy the branch of 1887 was drawn on transparent paper and made to coincide with that of 1885, especially in the points of steepest ascent and descent, the maximum brightness being the same in both cases. The two points previously marked as maxima then appeared separated by an interval of 8 days. The *middle* point of this interval being taken as the true maximum, the following results were obtained:

Maxima { 1885 March 11 / 1887 July 11 } Interval = 852 days.

Taking this interval as a basis, I have combined the two maxima into a mean light-curve. I shall give here, for the sake of future comparison, all the elements of reduction.

Table II.

Star	DM	$\alpha = 2^h$	δ (1855)	Steps	No. of obs.	Scale	Mag.
	M	m s	° ′				
g	7.5	16 50	+58 27.5	3.2	10	0.0	7.7
f	8.0	16 18	58 12.6	1.1	10	3.2	8.1
e	8.7	11 15	58 6.7	1.0	7	4.3	8.2
k	8.5	11 25	57 54.1	3.4	9	5.3	8.4
d	8.6	12 54	58 9.7	5.7	5	8.7	8.9
b	9.5	13 45	57 51.3	4.7	5	14.4	9.6
c	–	12 11	58 1.0	4.0	1	19.1	10.4
a	–	12 31	+57 56.3			23.1	(10.9)

1 step = $0^M.139$.

I find it convenient to put the arbitrary zero of the steps on the brightest star and to *count the steps in the order of the magnitudes*, in order to compare the two scales, as in the following table:

Table III.

Steps	Mag.	Steps	Mag.
0 =	7.7	12 =	9.3
2 =	7.9	14 =	9.6
4 =	8.2	16 =	9.9
6 =	8.5	18 =	10.2
8 =	8.8	20 =	10.5
10 =	9.1	22 =	10.7

In this table the DM. magnitude, $8^M.5$, has been chosen as corresponding to step 6, both numbers being the arithmetical means of the respective columns in Table II (excluding the stars *c* and *a*). The last column in Table II has been computed from Table III.

All the dates of the observations belonging to the two maxima of 1885 and 1887 were then changed into intervals before (—) and after (+) the two epochs, 1885 March 11 and 1887 July 11, respectively, and arranged into one series without distinction. The 48 available observations were combined into 22 *normal points* and a smooth curve was drawn between them, which is represented in the following table:

Table IV.

Days	Steps	Mag.	Days.	Steps.	Mag.
—180	13.4	9.5	+ 15	1.1	7.8
—165	11.5	9.3	+ 30	1.3	7.8
—150	9.7	9.0	+ 45	1.8	7.9
—135	8.0	8.8	+ 60	2.3	8.0
—120	6.5	8.6	+ 75	3.2	8.1
—105	5.0	8.3	+ 90	4.5	8.3
— 90	3.8	8.1	+105	6.0	8.5
— 75	2.8	8.0	+120	7.9	8.8
— 60	2.1	7.9	+135	9.5	9.0
— 45	1.8	7.9	+150	11.6	9.3
— 30	1.3	7.8	+165	13.5	9.5
— 15	1.1	7.8	+180	15.6	9.8
0	1.0	7.8	+195	17.6	10.1

Maximum brightness = 1.0 step = $7^M.8$.

This mean branch representing the maximum of the light-curve is a very regular flat line, almost resembling a parabola, though a little steeper in its descent. The observations indeed seem to indicate an inflection at each end of the branch, viz., between 150 and 180 days before and after maximum. This, however, will need farther confirmation.

The time of maximum of this mean curve was again determined geometrically, but no correction for the epochs before given was found.

II. *T Arietis.* (R.A. = 2^h 43^m.)

Five separate branches of the light-variations of this star were observed on 85 evenings, from 1883 Nov. 1, until 1888 March 13. When traced on a strip of paper, the vacant spaces (representing summer time) could be supplemented in such manner as to form a continuous wave line, showing the number of maxima and minima with great certainty. The following is the general aspect of the phases:

Table I.

Epoch	Minima	No. of obs.	Maxima	No. of obs.
14	1883 Dec.	25	1884 June	–
15	1884 Nov.	9	1885 Apr.	–
16	1885 Oct.	13	1886 Mar.	15
17	1886 Aug.	–	1887 Jan.	7
18	1887 June	–	1887 Nov.	15

The numbers of the epoch in the first column have been derived from the discussion below. For the determination of the period the minima appeared to be less adapted than the maxima, owing to an irregularity to be mentioned below, and of these only the last of 1887 was observed completely. Yet the points of equal brightness in the ascending and descending branches furnished a sufficient, and perhaps the best means of deriving the period, since the range of light-variation was to all appearances constant throughout those five years. The following are the results:

At 5 steps.	ascending	1886 Feb. 10 — 1887 Nov. 7 =	635^d = 2 × 317.5 days.	weight	1
10 "	"	1886 Jan. 20 — 1887 Oct. 16 =	634 = 2 × 317.0 "	"	2
10 "	descending	1883 Sept. 23 — 1887 Mar. 17 =	1271 = 4 × 317.8 "	"	4
10 "	"	1883 Sept. 23 — 1888 Jan. 22 =	1582 = 5 × 316.2 "	"	5
15 "	"	1883 Oct. 31 — 1888 Mar. 5 =	1587 = 5 × 317.4 "	"	4

The weight was supposed to be proportional to the multiplier of the period, except for the steps 5 and 15, where it was diminished by one unit, as 10 steps represent the most rapid change of light.

From these numbers we derive the probable value of the period between the years 1883 and 1887, as represented by my observations:

317.27 ± 0.23 days.

Assuming the epoch 18 = 1887 Nov. 29.6 (Greenwich time) for the last observed maximum, we find the following true maxima with their "Julian days."

Table II.

Epoch	Time	Julian Day
14	1884 June 8	2409336
15	1885 Apr. 21	09653
16	1886 Mar. 4	09970
17	1887 Jan. 16	10288
18	1887 Nov. 29	10605

The only observations published are those of Prof. Schönfeld.

E	Maxima	Julian Day	Maxima	Julian Day
0	1871 Dec. 13	2404775	–	–
1	1872 Nov. 8	05106	1873 Mar. 11	2405229
2	1873 Sept. 25	05427	1874 Jan. 28	05552
3	1874 Aug. 11	05747	1874 Dec. 16	05874

Professor Schönfeld derived the following successive periods: 328.5 days (*A.N.* Vol. 83, 1874); 324.0 (*Zweiter Catal.* 1875); and 322.7 days (*A.N.* Vol. 87, 1876).

The rate of these numbers, compared with the period 317.3 about the year 1885, seems to indicate a gradual decrease.

A mean light-curve was then constructed from the five branches. I first give the table of comparison-stars, with their intervals in steps and magnitudes.

Table III.

Star	DM.	$\alpha = 2^h$	δ 1855	Steps	No. of obs.	Scale	Mag.
	M	m s					
h	7.8	37 41	+16 23.8	6.7	5	0.0	7.9
g	8.7	39 20	35.7	2.0	7	6.7	8.4
e	8.6	39 16	44.2	4.0	10	8.7	[illegible]
c	8.8	39 36	41.2	2.0	2	12.7	[illegible]
d	8.9	39 48	60.4	4.2	6	14.7	9.0
a	9.5	40 11	48.8	3.4	2	18.9	[illegible]
b	9.5	39 23	55.1			22.3	9.6

1 step = $0^M.076$.

The zero of the scale has been put on the brightest star and the steps are counted *in the order of the magnitudes*, as in the case of *S Persei*, to obtain the following comparison of the two scales:

Table IV.

Steps	Mag.	Steps	Mag.
0 =	7.9	12 =	8.8
2 =	8.0	14 =	9.0
4 =	8.2	16 =	9.1
6 =	8.3	18 =	9.2
8 =	8.5	20 =	9.4
10 =	8.6	22 =	9.6

The starting points for this comparison are the values:

step 12 = $8^M.8$

these being the arithmetical means of columns 7 and 2, respectively, in the foregoing table III. Column 8 of the same table has subsequently been computed from this comparison.

TABLE V.

Days	Steps	Mag.	Days	Steps	Mag.
—210	15.4	9.1	— 50	11.5	8.8
—200	16.0	9.1	— 40	8.8	8.5
—190	16.0	9.1	— 30	6.6	8.4
—180	16.0	9.1	— 20	4.8	8.2
—170	15.9	9.1	— 10	3.9	8.2
—160	15.5	9.1	0	3.4	8.1
—150	14.5	9.0	+ 10	3.9	8.2
—140	13.0	8.9	+ 20	4.9	8.2
—130	13.9	9.0	+ 30	6.4	8.3
—120	15.9	9.1	+ 40	8.2	8.5
—110	17.2	9.2	+ 50	9.7	8.6
—100	17.1	9.2	+ 60	11.2	8.7
— 90	17.6	9.2	+ 70	12.6	8.8
— 80	17.1	9.2	+ 80	13.7	9.0
— 70	16.0	9.1	+ 90	14.4	9.0
— 60	13.7	9.0	+100	15.2	9.1

Maximum, $8^M.1$; Minimum, $9^M.2$

All the 81 available observations of the five sets between September 1883 and September 1888 having been combined into 37 normal points, as described in the case of *S Persei*; these gave the mean light-curve represented in table V.

The general character of this curve is that of a wave line, almost symmetrical around the maximum, the ascent being a little steeper than the descent. The minimum, however, shows an inflection, not unlike a secondary maximum, which appeared clearly in the curves, in January and in October, 1884, and indications of which were observed in 1885 and 1887. The existence of this secondary maximum, which seems to fall on the abscissa —134.5, or about 135 days before the principal maximum, remains to be confirmed by further observations. In any case, the minima between 1883 and 1885 seem to be less adapted to determining the period than the maxima. In fact, the star remained below its mean brightness (step 10.5 = $8^M.6$) for 227 days, or more than two-thirds of the whole period.

The time of maximum of the mean light-curve was then determined, and the correction, + 1.4 days, found to the assumed epoch (1887 Nov. 29.6), thus making the principal epoch:

E 18 = 1887 Dec. 1.0 Greenwich time.

This correction has been applied in constructing the preceding table V.

Georgetown College, 1890 *October* 10.

ON THE PRESENT ASPECT OF THE PROBLEMS CONCERNING LEXELL'S COMET,

BY S. C. CHANDLER.

Among the conclusions published a year ago, the writer indicated as the probable origin of the observed separation of this comet in 1889, the action of the satellites upon it, in its passage through the *Jovian* system in 1886. The relation of the comet's path to the orbits of the satellites was not particularly set forth at that time, because it was thought that the attempt to do so would force the interpretation of the results beyond what they would bear. But the recent interesting discussion of Mr. POOR (*A. J.* No. 228) accords so strikingly with the values first obtained, that we can now feel some confidence in conclusions upon this subject. Before considering it, however, it is appropriate to show the degree of accuracy with which the orbits employed represent the true conditions of approach to *Jupiter*, near the comet's aphelion point. To do this we may correct the elements by means of BARNARD's recent observations (*A.J.* No. 230). Compared with POOR's elements these give,

Greenwich M.T.	O — C. $\Delta\alpha$	O — C. $\Delta\delta$
	s	″
1890 Nov. 21.99986	— 4.48	+29.3
22.02000	— 4.52	+32.2

which, referred to the plane of the orbit, give — 68″.19 in longitude, and +9″.21 in latitude. Computing the differential coefficients in this system of coordinates, for this date and for 1889 Aug. 5.0 and Nov. 25.0, and putting 0 in the second members of the equations for the last two mentioned dates, we have,

$$\begin{array}{rrrrrrl}
+1.6132\,\Delta\chi' & -\;49470\,\Delta e & -2530.9\,\Delta T & +\;44448\,\Delta q & & & =\;0 \\
+1.3145\,\Delta\chi' & +\;42060\,\Delta e & -2091.8\,\Delta T & -\;21897\,\Delta q & & & =\;0 \\
+1.1088\,\Delta\chi' & -197070\,\Delta e & -\;593.3\,\Delta T & -178530\,\Delta q & & & =-68.19 \\
+0.0509\,\Delta\chi' & +\;294.0\,\Delta e & -\;48.98\,\Delta T & +\;16332\,\Delta q & -0.7549\,\Delta\Omega' & -0.7568\,\Delta i' & =\;0 \\
+0.0350\,\Delta\chi' & +\;52.8\,\Delta e & -\;37.93\,\Delta T & -\;9179\,\Delta q & -0.6625\,\Delta\Omega' & +0.5500\,\Delta i' & =\;0 \\
-0.0070\,\Delta\chi' & -\;3527.2\,\Delta e & +\;10.73\,\Delta T & +\;473\,\Delta q & +0.2084\,\Delta\Omega' & +1.0673\,\Delta i' & =+\;9.21
\end{array}$$

the solution of which gives, putting $\Delta\omega' = \Delta\chi' - \cos i' \; \Delta\Omega'$,

$$\Delta\omega' = +98''.44 \qquad \Delta e = +0.0003272$$
$$\Delta\Omega' = +\ 3.06 \qquad \Delta q = +0.0004305$$
$$\Delta i' = +\ 8.92 \qquad \Delta T = +0.06561$$

The accented symbols are referred to the equator. Reducing them to the ecliptic, and applying to Poor's elements, we have the corrected elements C'', which will closely represent all the observations for nineteen months since discovery, covering nearly 150° of anomaly, and must be exceedingly close to the true values. They are referred to the ecliptic and equinox of 1890.0.

	C''	C	P
T	Sept. 30.32835	+0^d.31645	+0^d.0651
π	1° 34′ 49″.62	+8′ 32″.32	+1′ 40″.92
Ω	17 58 43 .64	— 1 .66	— 8 .32
i	6 4 17 .12	+ 6 .62	+ 9 .17
e	0.4706857	—0.0000183	+0.0003272
a	3.6837239	—0.0009581	+0.0030883
q	1.9498476	—0.0003814	+0.0004305
Period	7.0702 yrs.	—0.0028 yrs.	+0.0089 yrs.

In the column P are the corresponding corrections to Poor's orbit, based on more than seven months' observations, and in C those to my orbit (*A.J.* No. 205), which embraced only a little over three months. Now, by the corrected orbit, C'', the comet was at aphelion, near which the encounter with *Jupiter* occurred, 1886 Mar. 18.881. Taking its position in space at this instant as origin of a system of ecliptical coordinates, the relative positions assigned by C and P are as follows,

	C	P
x	—0.000231	+0.004195
y	—0.004398	+0.005028
z	—0.000416	+0.000603
Δ	0.004424	0.006771

Thus the true place of the comet was probably nearly between those assigned by C and P, and the differences are of such an order that we can feel assured that the orbits relative to *Jupiter* by both computations are very nearly correct. The two hyperbolic orbits about Jupiter are

	C	P
T	1886 May 20.75	1886 July 1.17
π	291° 52′.6	297° 10′.0
Ω	212 20 .6	211 28 .7
i	37 55 .5	35 33 .5
e	1.05796	1.10566
a	—0.16929	—0.09000
q	0.00981	0.00951

The agreement is satisfactory, but Poor's are much nearer the true values, since they eliminate the perturbations more thoroughly. Now by both of these orbits the comet passed the ascending node of its orbit upon that of the fourth satellite just inside the track of the latter. According to C this occurred 1.20 days before perijove at a distance from *Jupiter* of 0.0113; and by P, 1.25 days before at a distance of 0.0121. The satellite's distance is 0.0130, and the radius of its sphere of attraction is 0.0002. The actual diameter of the comet is a somewhat uncertain quantity, but may be reasonably estimated at perhaps 0.0006. Thus the outer portion of the coma passed barely inside of the circle which represents the limit between the controlling activity of the planet and the fourth satellite, and if the latter were at this part of its orbit at the time of the comet's passage, the disturbing action upon the nearer and remoter portions of the comet's volume would be enormously different. If, as is abundantly consistent with the uncertainty of the calculation, a portion of the coma obtruded itself into the satellite's attraction-sphere, the result would be, with a low degree of cohesion, that this portion would be diverted for a time into a hyperbola around the satellite, and in emerging from its control, and in turn from that of *Jupiter*, would resume its course about the sun as a separate body from the main comet. We have very strong ground for presumption that this was what actually occurred, in the fact that the orbits of the companion comets seen in 1889, according to Bredichin, intersect that of the main body at the point of longitude where the encounter with *Jupiter* occurred in 1886.

Further, the tail of the comet, seen in 1889 very much foreshortened, but still from 6′ to 15′ in apparent length, would, as it passed through the plane of the orbit of the fourth satellite, lie almost precisely along the track of the latter for a distance equivalent to about two days' motion, or thereabouts, of the satellite, so that the chance of its interception of some portion of the tail is considerable. No inference can yet be drawn from comparisons with the satellites's place, the position of the comet in its orbit being uncertain by several days; but subsequent investigation will enable us to settle this point definitely, in all probability.

The topic here discussed has an exceedingly important bearing upon the identity with Lexell's comet. Some doubt has been expressed by Schulhof in respect thereto, on the ground that Tisserand's criterion gives somewhat discordant values for the two comets. But not only is this criterion inapplicable in case of important perturbations by Saturn between 1779 and 1886 — and such perturbations, I may incidentally remark, did probably occur either about 1799 or 1827 — but also in the case of any disturbance by the fourth satellite, the great probability of which has, I think, just been shown. The elegant and curious relation of Tisserand depends essentially upon equality of the velocities with which the comet entered into and emerged from the planet's attraction-sphere. But this equality may easily be disturbed by the action of a satellite during the transit, sufficiently to account for the observed discordance in question, although not enough to destroy the general similarity of the orbits about the sun, of LEXELL and 1889 V, after 1779 and before 1886, respectively.

Another remark on this question of identity is essential. In my article of a year ago, the perturbation of *Jupiter* was shown to have changed the period from 27.0 years to its present one. The value just obtained by Mr. POOR is 28.18 years, which apparently destroys the fine coincidence by which the first result carried back the comet to *Jupiter* in 1779, making the date of appulse 1775 instead. But it will be seen that the period at the time of entry into the attraction-sphere was 29.73 years, and had been diminished more than a year and a half simply by the perturbations during the previous fifty days. But even at the beginning of this interval the comet was at a very moderate distance from *Jupiter*, which had been very slowly approaching it for a long time — the distance being only 0.6, for instance, six months previous — during which time the period was lengthening probably very considerably. I would suggest that if Mr. POOR carries the perturbations back about a year from where he left them, he will probably find a period not far from what I gave, and confirm the relation of four periods of the comet to nine of *Jupiter*, and their consequent conjunction in 1779.

Cambridge, 1890 *Dec.* 8.

COMETS *e* 1890 (*ZONA, Nov. 15*) AND *f* 1890 (*SPITALER, Nov. 16*).

BY E. E. BARNARD.

The telegram announcing the discovery of ZONA's comet was not received at the Lick Observatory until the forenoon of Nov. 17. The following is the only observation of this comet which it has been possible to obtain since the moon withdrew — our bad weather having set in the following day. At this observation I could hardly believe the object was the same that I had observed on Nov. 17, 18 and 19. Then it was about 12^M, round, gradually brighter in the middle, with no trace of a nucleus. On Nov. 30, it was smaller, brighter, and had a perfectly stellar nucleus of $11\frac{1}{2}^M$. So much did the nucleus resemble a star that I waited some time before beginning observations for the comet to pass from over it. When the moon rose scarcely any nebulosity could be seen about the nucleus, and it would then never have been taken for a comet. A comparison with Mr. CAMPBELL's ephemeris, however, showed that it must be the same object previously observed. The change was singularly remarkable, considering the comet was so far past perihelion.

No announcement, telegraphic or otherwise, was received here at all of the discovery of a comet* by SPITALER on Nov. 16, until the arrival of the *Science Observer Circular*, which was not received until Dec. 2, so that no opportunity has occurred to search for it, as the storm continues.

Mt. Hamilton, 1890 *Dec.* 4.

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* Except, indeed, a vague reference to one other comet somewhere near ZONA's, in a letter from SWIFT, received at the time of full moon.

Mr. BARNARD has communicated a full observation of Comet *e*, giving the position,

Mt. Hamilton M.T.	α	$\log p\Delta$	δ	$\log p\Delta$
1890 Nov. 30 $8^h\ 53^m\ 50^s$	$1^h\ 6^m\ 39^s.2$	$n9.539$	$+35°\ 7'\ 28''.0$	0.076

The details are postponed until the next number, in order to leave room for his observation of Comet *f*, which has been transmitted by telegraph, but did not reach the Editor until this present number of the *Journal* had been sent to the press. This is:

$$1890\ \text{Dec. } 6.7797\ \text{Greenwich M.T.} \qquad \alpha = 5^h\ 13^m\ 10^s.7, \qquad \delta = +37°\ 48'\ 55''.$$

A hasty computation indicates that the comet is approaching the earth, and that its perihelion, which is at about 90° longitude, will be passed not far from the close of the year; the longitude of the node being about 60°, the inclination nearly 30°, and the perihelion distance very large, nearly 3.0. The inequality of the intervals and the great distance of the comet make it impracticable to furnish a trustworthy ephemeris within the short time available.

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COMETS *e* AND *f* 1890, BY PROF. E. E. BARNARD.

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LAPLACE'S SOLUTION OF THE TIDAL EQUATIONS.

By WILLIAM FERREL.

In this paper, supplementary to that under the same heading in Vol. IX, no. 6 of the *Astronomical Journal*, it is proposed to explain more fully a certain point in the latter which did not appear clear to a correspondent some time since, by presenting the matter more in detail, and also to clear up some doubts held by some with regard to the convergency of the series in the tidal expression.

In Darwin (34), we have the following differential equation to be satisfied, which is equivalent to that of Laplace:

$$(1)\qquad r^2(1-r^2)\frac{d^2u}{dr^2} - r\frac{du}{dr} - (8-2r^2-\beta r^4)u + \beta E r^6 = 0$$

in which u is the difference between the real amplitude of the tide and that given by the equilibrium theory, $r = \sin\theta$ is the sine of the geographical polar distance θ, Er^2 is the amplitude of the equilibrium tide, and

$$(2)\qquad \beta = \frac{4n^2}{gl}$$

in which $n^2/g = \frac{1}{289}$ and l is the depth of the ocean, supposed to be uniform, in terms of the earth's radius.

Putting

$$(3)\qquad u = K_2r^2 + K_4r^4 + K_6r^6 \;.\;.\;.\;.\;.\; K_nr^n$$

in which n is any even number, corresponding with the exponent, and substituting this value of u and its derivatives in (1) above, we get, by equating the coefficients of like powers of r to 0,

$$K_2 = 0,\quad 12K_4 - 12K_4 = 0,\quad 16K_6 + \beta E = 0,\ \&c.,$$

and generally, after K_6,

$$(n(n-2)-8)K_n - ((n-2)(n-3)-2)K_{n-2} + \beta K_{n-4} = 0$$

From these equations we get the following expressions of K_n:

$$K_2 = 0$$

$$K_4 = K_4$$

$$(4)\qquad K_6 = \tfrac{5}{8}K_4 - \tfrac{1}{16}\beta E$$

$$K_8 = (\tfrac{7}{16} - \tfrac{1}{40}\beta)K_4 - \tfrac{7}{160}\beta E$$

$$K_{10} = (\tfrac{21}{64} - \tfrac{79}{2880}\beta)K_4 - (\tfrac{21}{640} - \tfrac{1}{1152}\beta)\beta E$$

and generally, after K_6,

$$(5)\qquad K_n = \frac{n-1}{n+2}K_{n-2} - \frac{\beta}{(n+2)(n-4)}K_{n-4}$$

This general expression is equivalent to Laplace's and Darwin's law as given in my preceding paper, equation (2), but is more simple and convenient in deducing any coefficient K_n from the last two preceding. The one is reducible to the other by putting $n = 2i + 4$. The general law of (5) does not hold until after K_6, but K_4 and K_6 being obtained from the direct equation of the coefficients of r^4 and r^6, then, by means of these, K_8 is obtained, either directly from the equation of the coefficients, or from the general expression of (5), and this law can be extended forward, but not backward. For instance, K_6 is not obtainable from K_4 and K_2. As is usual in such cases, the general law is not obtained until after several equations of the coefficients. This law determines nothing, but is itself determined by the equations of the coefficients, and when the values of K_n are given directly in this way, and not by the general law, the former must be taken, and the general law, which is a relation found between the coefficients after K_6 only, cannot be extended back.

Putting h for the amplitude of the real tide, we have, from what has been stated above,

$$h = Er^2 + u = Er^2 + K_4r^4 + K_6r^6 \;.\;.\;.\;.\;. + K_nr^n \qquad (6)$$

Laplace extended the relation above, found to exist between the coefficients of r in (3), and after K_6 only, back so as to make it, by means of the continued fraction, determine the value of K_4 and so the relation between Er^2 and u. This makes K_4 a determinate quantity, whereas the equation of the coefficients of r^4 gives $K_4 = K_4$, an indeterminate quantity. It is evident that any value of K_4 satisfies the differential equation, and so, with the other coefficients depending upon it, is a solution of the tidal equation.

The extension of the general relation of (5) back so as to make it determine K_4, and the relation between Er^2 and u in (6), was regarded by the writer in his previous paper as an extension of the law back where it is not applicable, and this is what was not clearly understood by his correspondent.

From (4) it is seen that the tidal expression consists of two parts, one of which depends upon K_4, and is independent of the tidal forces contained in E, and the latter depends upon these forces. It is evident that the former can exist without the latter. Also that, being independent of the forces, and dependent simply upon certain initial motions which the sea may be supposed to have independent of the forces, it must vanish when there is friction, and so K_4 must be put equal to 0 in the real case of nature.

We come now to the second part of what we have proposed to consider here, namely, the convergency of the series in the expression of u in (3). Inasmuch as the vanishing ratio between consecutive values of K_n is unity, as is readily seen from an inspection of (5), it has been said that the device of LAPLACE in the use of the continued fraction was necessary to make the expression of u convergent at the equator where $r = 1$, so as to give a finite value of u. It is true that the expression at first is more convergent with a large value of K_4, such as is given by the continued fraction, but still the vanishing ratio in any case is unity. But it can be shown that the expression gives a finite value of u even when we put $K_4 = 0$.

We get by development, (7)

$$(1-r^2)^{1/2} = 1 - \tfrac{1}{2}r^2 - \tfrac{1}{8}r^4 - \tfrac{1}{16}r^6 \; .\;.\;.\;. - A_n r^n = 1 + \Sigma_2^\infty A_n r_n$$

in which the relation between each coefficient A_n and the preceding one, commencing with $-\frac{1}{2}$, is

$$(8) \qquad A_n = \frac{n-3}{n} A_{n-2}$$

Hence we have, when $r = 1$

$$(9) \qquad \Sigma_2^\infty A_n = -1$$

$$(10) \qquad \Sigma_{n'+2}^\infty A_n = -(1 + \Sigma_2^{n'} A_n)$$

in which n' is the exponent of any assumed term in the series.

The expression of (5) above may be put into the form,

$$(11) \quad K_n = \frac{n-3}{n} K_{n-2} + \frac{6}{n(n+2)} K_{n-2} - \frac{\beta}{(n+2)(n-4)} K_{n-4}$$

From this, by means of (8), we get for any coefficient of which the characteristic is n',

$$(12) \qquad K_{n'} = \frac{K_{n'-2}}{A_{n'-2}} A_{n'} F_{n'}$$

in which, (13)

$$F_{n'} = \left(1 + \frac{6}{(n'+2)(n'-3)} - \frac{n'\beta}{(n'+2)(n'-4)(n'-3)}\right) \frac{K_{n'-4}}{K_{n'-2}}$$

And putting $n'+2$ for n' in (12) we get

$$K_{n'+2} = \frac{K_{n'}}{A_n} A_{n'+2} F_{n'+2}$$

$$K_{n'+4} = \frac{K_{n+2}}{A_{n+2}} A_{n'+4} F_{n'+4}$$

This becomes by substituting for $K_{n'+2}/A_{n'+2}$ its value derived from the preceding expression, becomes,

$$K_{n'+4} = \frac{K_{n'}}{A_{n'}} A_{n'+4} F_{n'+2} F_{n'+4}$$

In like manner we get generally

$$(14) \qquad K_{n'+i} = \frac{K_{n'}}{A_{n'}} A_{n'+i} F_{n'+2} F_{n'+4} \; .\;.\;.\;. F_{n'+i}$$

in which the values of the factors $F_{n'+2}$, $F_{n'+4}$, $F_{n'+i}$ are given by (13) by adding 2, 4, and i respectively to n' in that expression.

Now, all these factors are finite, and hence, putting now K_n for its equivalent, $K_{n'+i}$ and A_n for $A_{n'+i}$, we have

$$\Sigma_{n'+2}^\infty K_n = \text{a finite quantity}$$

since by (10)

$$\Sigma_{n'+2}^\infty A_n = \text{a finite quantity.}$$

From (13) and (14) it is seen that any coefficient, taken without regard to signs,

$$K_{n'+i} < \frac{K_{n'}}{A_{n'}} A_{n'+i} \qquad (15)$$

when

$$\beta > \frac{6(n'+i-1)}{n'+i} \frac{K_{n'+i-2}}{K_{n'+i-4}} \qquad (16)$$

since when this condition is satisfied all the factors $F_{n'+2}$, $F_{n'+4}$, ... $F_{n'+i}$ are less than unity. Therefore, we have, putting n for $n'+i$, (17)

$$\Sigma_{n'+2}^\infty K_n < \Sigma_{n'+2}^\infty \frac{K_{n'}}{A_{n'}} A_n, \text{ or, by (10), } < -\frac{K_{n'}}{A_{n'}}\left(1 + \Sigma_2^{n'} A_n\right)$$

when

$$\beta > 6 \qquad (18)$$

since this is what (16) becomes when i is infinitely great. This is simply the limiting condition in all cases, and the first number of (17) is generally less than the second when β is considerably less than 6.

We have from (3)

$$u = \Sigma_2^\infty K_n = P_{n'} + Q_{n'} \qquad (19)$$

in which

$$\left.\begin{aligned} P_{n'} &= \Sigma_2^{n'} K_n, \\ Q_{n'} &= \Sigma_{n'+2}^\infty K_n < -\frac{K_{n'}}{A_{n'}}\left(1 + \Sigma_2^{n} A_n\right) \end{aligned}\right\} \qquad (20)$$

With the values of $P_{n'}$ and $Q_{n'}$ (19) gives u, and this in (6) gives h, the amplitude of the tide.

LAPLACE computed the values of $2h$, that is, the range of the tides at the equator, at the times of conjunction of the moon and sun, for the several values of β equal 10, 40, and 5, to which, by (2), correspond the several values of l, the depth of the ocean, equal to $\frac{1}{2890}$, $\frac{1}{722.2}$, and $\frac{1}{361.1}$ of the earth's radius, or approximately 1.4, 5.5 and 11 miles respectively.

Taking as an example the case in which $\beta = 10$, we get from (4) and (5) by putting $K_4 = 0$, the following values of K_n in terms of E in the last column of the following table, and from (7) and (8) the corresponding values of A_n in the second column.

n	A_n	K_n
2	−0.50000	
4	12500	
6	6250	−0.6250
8	3906	4375
10	2734	2413
12	2051	1505
14	1611	1072
16	1309	823
18	1091	661
20	927	548
. .	.	. .
40	322	172
. .	. .	. .
60	174	91

Putting n' equal 20, 40, 60, we get the following corresponding values from this table when complete for all the values of n from 2 to 60,

$$A_{20} = -.00927 \qquad 1 + \Sigma_2^{20} A_n = .17621$$
$$A_{40} = -.00322 \qquad 1 + \Sigma_2^{40} A_n = .12536$$
$$A_{60} = -.00174 \qquad 1 + \Sigma_2^{60} A_n = .10251$$

From the values of K'_n we likewise get

$$K_{20} = -.0548 \qquad K_{20}/A_{20} = 5.91 \qquad P_{20} = -1.7647$$
$$K_{40} = -.0172 \qquad K_{40}/A_{40} = 5.18 \qquad P_{40} = -2.0488$$
$$K_{60} = -.0091 \qquad K_{60}/A_{60} = 5.23 \qquad P_{60} = -2.1687$$

We therefore get from (19) and (20) with the preceding data,

$$u < -\ 1.7647 - 5.91 \times .17621 \text{ or } < -\ 2.8061$$
$$u < -\ 2.0488 - 5.18 \times .12536 \text{ or } < -\ 2.7157$$
$$u < -\ 2.1687 - 5.23 \times .10254 \text{ or } < -\ 2.6870$$

and so on, according as we take $n' = 20, 40, 60$, or still greater values. It is seen that the first value, in which we get the value of $P_{n'}$ from summing the actual values of K'_n from $n = 6$ to $n = n'$, and then get the sum of the remaining infinite number of terms approximately from the last of (20), differs but little from the last value, in which the value of $P_{n'}$ was obtained from summing the actual values of K'_n up to $n' = 60$, and then obtaining the sum of the remaining terms from the last of (20). It is evident that the real value of u must be only a very little less negatively then -2.6870. The several values of u differ the less, the more nearly the condition of (16) is satisfied, which, when the value of n' is large, is very nearly that of (18). In our example $\beta = 10$, and so is too large to give equal values in the several cases of $n' = 20, 40$, or 60. With $\beta = 40$ there is much greater difference in the several values, and the uncertainty in the last value is consequently much greater, but the last number so obtained, is always a limit below which the real value is.

Since our values of K'_n have been computed in terms of E, the value of u above must be multiplied into E. With this value, then, we get from (6) for the value of h at the equator, where $r = 1$,

$$h = (1 - 2.687)\ E = -1.687\ E$$

The value of E is that of the amplitude of the equilibrium tide at the equator, which in the case of the lunar tide, if we assume the moon's mass equal $\frac{1}{80}$, is 0.812 of a foot. Hence we get for the range of the lunar tide approximately at the equator,

$$2h = -2 \times 1.687 \times 0.812 = -2.74 \text{ feet.}$$

Its being negative indicates that low water occurs at the time of the moon's meridian transit.

Laplace, in the same case, obtained for the range of the tide for the moon and sun in conjunction or opposition, 11.05 meters, which, being positive, indicates that high water occurs at the time of meridian passage. But instead of $K'_4 = 0$, he used $K'_4 = 6.196$, obtained from his continued fraction. Besides, the mass of the moon which he used was much too large.

Martinsburg, W. Va., December 3, 1890.

OBSERVATIONS OF COMETS,

MADE WITH THE 15-INCH EQUATORIAL OF THE HARVARD COLLEGE OBSERVATORY,

By O. C. WENDELL, Assistant.

Communicated by Professor Edward C. Pickering, Director.

1890 Cambridge M.T.	✱	No. Comp.	☄ — ✱ $\Delta\alpha$	☄ — ✱ $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for
Comet *e* 1890 (Zona *Nov. 15*).								
			m s	′ ″	h m s	° ′ ″		
Nov. 28 8 28 33	1	5	−2 52.92	+ 8 27.5	4 19 10.09	+35 9 53.1	*n*9.612	0.383
Dec. 15 8 25 9	2	4	−3 9.48	+14 55.1	2 53 24.49	+32 58 8.3	*n*9.043	0.175
Comet *f* 1890 (Spitaler, *Nov. 16*).								
*Dec. 22 17 25 19	3	5	+1 16.25	− 2 1.8	4 59 44.07	+39 23 56.8	*n*9.746	0.715

Mean Places for 1890.0 of Comparison-Stars.

✱	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	4 21 59.19	+3.82	+35 1 15.8	+ 9.8	Weisse's Bessel, IV, 416–18 (mean)
2	2 56 30.50	+3.47	+32 12 51.8	+18.4	Weisse's Bessel, II, 1302
3	4 58 23.48	+1.34	+39 25 49.5	+ 9.1	Lalande 9487

* The object observed for Spitaler's comet could not be identified as such with certainty on account of faintness, rather low altitude, and haze. It was, however, in the place indicated by the ephemeris, and was thought to be the comet. As soon as the moon and weather will permit, a reexamination of this region will be made to see if the assumed object is still there.

OBSERVATIONS OF μ' *HERCULIS*,

BY A. HALL.

[Communicated by the Superintendent.]

Date.	p	s
	°	″
1880.581	245.9	0.95
0.603	246.3	1.09
0.712	245.6	0.98
0.718	247.3	1.00
1880.654	246.28	1.005
1881.503	249.8	1.00
1.522	250.6	1.10
1.536	250.5	1.12
1.588	245.5	0.93
1.591	249.0	0.89
1881.548	249.08	1.008
1882.514	256.9	0.74
2.519	258.1	0.72
2.525	264.1	0.66
2.538	257.4	0.69
1882.524	259.12	0.702
1883.573	262.9	0.64
3.581	264.7	0.61
3.598	261.2	0.74
1883.584	262.93	0.663
1884.635	274.3	0.64
4.638	272.4	0.67
4.657	273.4	0.64
1884.643	273.37	0.650
1885.553	286.2	0.59
5.561	288.5	0.59
5.561	289.4	0.65
1885.559	288.03	0.610

Naval Observatory, 1890 *Dec.* 3.

Date.	p	s
	°	″
1886.555	303.9	0.39
6.560	303.7	0.41
6.571	300.2	0.35
6.640	292.2	0.38
6.651	300.6	0.40
1886.596	300.12	0.386
1887.565	319.8	0.45
7.571	322.3	0.41
7.595	322.3	0.41
1887.577	321.47	0.423
1888.611	337.3	0.36
8.625	338.5	0.37
8.649	342.9	0.40
8.652	347.1	0.42
1888.631	341.45	0.388
1889.630	356.5	0.29
9.619	0.8	0.33
9.663	1.5	0.32
9.665	3.7	0.41
1889.651	0.62	0.345
1890.536	12.9	0.46
0.542	13.6	0.54
0.555	13.7	0.52
0.577	12.7	0.53
1890.552	13.22	0.512

NOTE. — This double star was discovered by ALVAN CLARK in 1856. An observation by DAWES gave,

1857.5. $p = 59°.3$; $s = 1''.82$

It will be seen that the angular motion is rapid, and indicates a period of less than fifty years. This star is interesting, since it makes it probable that some of the faint pairs found in recent years may have large motions.

ON *JUPITER'S* PERTURBATION OF COMET 1889 V IN 1922.

BY S. C. CHANDLER.

In *A.J.* no. 205, it was stated that the orbit into which this comet was thrown by *Jupiter* in 1886, and in which it is now moving, is such "that no serious perturbation can occur until 1921, in the spring of which year, however, it will again enter the sphere of *Jupiter's* activity, and undergo another violent transmutation."

Shortly after, a closer examination of the circumstances of this anticipated appulse was made, but not published, because I was not quite sure of the trustworthiness of the result of carrying forward so far the mean motion I then used, 501″.656. But the corrected motion found in *A.J.*, no. 231, differs only 0″.196 from this, which corresponds to but four or five days' difference in heliocentric motion in thirty-three years; and the comet's aphelion was so accurately fixed by the old orbit, as is shown in no. 231, that the computation above spoken of has practically as much value, for the purpose of exhibiting the character of the appulse, as if based on the corrected orbit. The results may, therefore, have enough interest to be communicated here, with such brief details as will lighten the labor of any one who may feel disposed to carry the matter further.

The elements on p. 101 (Vol. IX) carried forward to 1920.0, give. $\pi = 1° 51' 25''.1$, $\Omega = 18° 22' 54''.9$, $i = 6° 4' 23''.8$; whence the ecliptical coordinates,

$$x = r\,[9.9997582]\,\sin[\;91°\;45'\;38''.4 + v]$$
$$y = r\,[9.9978000]\,\sin[\;\;1\;\;57\;\;13\;.3 + v]$$
$$z = r\,[9.0244869]\,\sin[343\;\;28\;\;30\;.2 + v]$$

By LeVerrier's Tables of *Jupiter*, we find (Equinox 1920.0),

Gr. M.T.	l	b	log r
	° ′ ″	° ′ ″	
1922 Jan. 15.0	187 59 46.13	+1 18 29.76	0.7364763
Feb. 4.0	189 30 28.55	+1 18 31.65	0.7365309
Feb. 24.0	191 1 9.64	+1 18 30.26	0.7365707

We thus obtain for the instant 1922 Feb. 4.0, from the undisturbed orbit, the position and motion of the comet relative to *Jupiter*, expressed by,

$$\xi = +0.171904,\qquad \eta = -0.273897,\qquad \zeta = -0.068488$$
$$\frac{d\xi}{dt} = +0.00090738,\quad \frac{d\eta}{dt} = +0.00199270,\quad \frac{d\zeta}{dt} = -0.00058545$$

From these we deduce a subsequent hyperbolic motion about *Jupiter*, with a very large parameter, 1.5555. The nearest point of approach occurs on 1922 June 12.160 at a distance of 0.28512. The plane of the motion is inclined to the ecliptic 26° 55′.2, the ascending node being at 98° 51′.5, and the perijove at 210° 31′.4 from this node, all referred to 1920.0. The comet in receding from *Jupiter* attains on 1922 Oct. 18.920 the same distance as on Feb. 4.0.

It will consequently be seen that the nature of the case precludes any such violent disturbance in 1922, as in 1886, although the changes in the elements will doubtless be great. I have not carried forward the calculation to determine these, but from what has been given any one interested can easily do so. But in that case it would be desirable, since the comet penetrates so slightly into the attraction-sphere of *Jupiter*, to take into account, approximately, the perturbations by the sun between Feb. 4 and Oct. 18.

Cambridge, 1890 *Dec.* 23.

I desire to note two slips of the pen on p. 120. In line 13, col. 1, read "increased" for "diminished"; and in line 5, col. 2, read "four" for "six," the word "previous" of course referring to Mar. 20.

FILAR-MICROMETER OBSERVATIONS OF COMET *f* 1890 (*SPITALER, Nov. 16*),

MADE WITH THE 12-INCH EQUATORIAL OF THE LICK OBSERVATORY.

BY E. E. BARNARD.

On December 6, the telegram containing the additional observation of this comet on Dec. 4 was received at this Observatory. That evening and the following proving clear the comet was found and observed with the 12-inch equatorial. It is of about the 13th magnitude, and is very small, only a few seconds in diameter; it has an indefinite brightening in the middle. The appearance is that of a very distant comet.

1890 Mt. Hamilton M.T.	*	No. Comp.	☄ — * Δα	☄ — * Δδ	☄'s apparent α	☄'s apparent δ	log p Δ for α	log p Δ for δ
d h m s			m s	′ ″	h m s	° ′ ″		
Dec. 6 10 36 8	1	18 , 6	+0 32.11	+1 13.0	5 13 10.65	+37 48 55.1	n9.369	9.177
7 9 48 5	2	18 , 8	+0 11.21	−3 18.1	5 12 18.05	+37 58 18.2	n9.522	9.790
8 14 22 11	3	11 , 6	−0 53.23	+7 53.3	5 11 10.63	+38 9 29.8	9.511	9.815
9 9 18 50	4	3 , 4*	−0 11.07	+6 11.8	5 10 27.63	+38 16 12.5	9.598	9.982
10 8 17 37	5	3 , 1*	−0 8.16	+1 54.9	5 9 31.	+38 25	n9.681	0.153
11 9 51 9	6	12 , 4	−0 36.14	+3 21.8	5 8 39.72	+38 33 27.8	n9.711	0.281
14 8 1 28	7	16 , 3	−0 22.85	+3 27.3	5 5 51.7	+38 56.6	n9.863	0.119

Mean Places for 1890.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	5 12 34.45	+1.09	+37 47 36.7	+5.7	Lalande 9881
2	5 11 59.73	+1.11	+38 1 30.1	+5.9	Lalande 9860
3	5 11 59.73	+1.13	+38 1 30.4	+6.1	Lalande 9860
4	5 10 31.55	+1.15	+38 10 21.5	+6.2	† Compared with star 3
5	5 9 38.	+1.18	+38 23	+6.3	9ᴹ.7 star, approximate place
6	5 9 11.66	+1.20	+38 29 59.4	+6.6	W.B. 5ʰ 161
7	5 6 10.2	+1.28	+38 53.0	+7.3	DM. 38° 1065

---

* Δα measured direct with micrometer.

† Star 3 — Star 4, $\Delta\alpha = -1^{m}\,25^{s}.18$, $\Delta\delta = +8'\,51''.1$. Two observations.

The above observations are all that it has been possible to obtain of the comet. It seems to be getting a little larger, and a [illegible] brighter.

Mt. Hamilton, 1890 *Dec.* 18.

FILAR-MICROMETER OBSERVATIONS OF D'ARREST'S COMET (*d 1890*),

MADE WITH THE 26-INCH EQUATORIAL OF THE LEANDER MCCORMICK OBSERVATORY OF THE UNIVERSITY OF VIRGINIA.

[Communicated by the Director.]

1890 Local M.T.	*	No. Comp.	☄ — * Δα	☄ — * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ	Obs.
d h m s			m s	′ ″	h m s	° ′ ″			
Oct. 17 9 4 8	1	1 , 1	+7 5.79	+3 46.0	19 57 56.52	—27 44 46.1	9.554	0.856	S
30 6 47 32	2	1 , 2	—7 31.86	—1 56.7	20 50 17.95	27 59 54.3	8.895	0.907	S
31 7 22 27	2	1 , 2	—3 28.32	+1 9.6	20 54 21.47	27 56 48.0	9.194	0.898	P
Nov. 1 6 58 28	2	6 , 2	+0 23.72	+4 37.7	20 58 13.50	27 53 19.9	9.020	0.902	P
7 32 46	3	2 , 2	—2 25.99	—3 47.5	20 58 18.25	27 53 10.9	9.252	0.896	S
7 34 15	2	2 , 2	+0 29.32	+4 46.5	20 58 19.10	27 53 11.1	9.261	0.895	S
4 8 8 34	4	2 , 2	—3 23.03	+1 13.3	21 10 2.13	27 39 4.5	9.403	0.883	D
8 41 42	5	3 , 2	—1 11.18	+2 15.7	21 10 8.36	27 38 56.2	9.502	0.867	P
8 41 42	4	3 , 2	—3 16.75	+1 22.2	21 10 8.41	27 38 55.6	9.502	0.867	P
5 6 36 1	6	5 , 4	—1 50.66	+1 49.4	21 13 38.84	27 33 45.6	8.721	0.904	P
7 31 45	6	4 . 4	—1 42.15	+2 5.2	21 13 47.35	—27 33 29.8	9.247	0.895	S

Mean Places for 1890.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	19 50 19.01	+1.69	—27 48 35.1	—0.4	Yarnall 8788
2	20 57 17.95	+1.86 +1.83	27 57 59.2	+1.6	Gould, ½(G.C. 28864+C.Z. 1808)
3	21 0 42.39	+1.85	27 49 25.1	+1.7	" ½(G.C. 28950+C.Z. 1902)
4	21 13 23.28	+1.88	27 40 19.9	+2.1	" ½(G.C. 29239+C.Z. 375)
5	21 11 17.68	+1.86	27 41 13.8	+1.9	" ½(G.C. 29203+C.Z. 312)
6	21 15 27.63	+1.87	—27 35 37.1	+2.1	" ½(G.C. 29283+C.Z. 460)

S = ORMOND STONE; *P* = N. M. PARRISH; D = C. L. DEMOTT.

OBSERVATIONS OF COMET *e* 1890 (*ZONA*),

MADE AT THE U.S. NAVAL OBSERVATORY WITH THE 9.6-INCH EQUATORIAL,

BY E. FRISBY.

[Communicated by the Superintendent.]

1890 Washington M.T.	*	No. Comp.	☄ — * Δα	☄ — * Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
d h m s			m s	′ ″	h m s	° ′ ″		
Nov. 28 6 26 55.5	1	20 . 4	—0 26.29	+1 26.4	4 19 34.64	+35 9 36.3	n9.7384	0.5581
Dec. 4 10 38 52.4	2	20 . 4	+0 4.09	—0 14.4	3 44 38.51	+34 47 46.7	8.4023	9.7167
10 11 30 12.5	3	10 . 2	—2 27.88	—6 26.1	3 14 22.16	+33 55 30.0	9.3496	0.0270
11 10 33 5.7	4	15 . 3	—1 58.74	—1 54.6	3 9 55.52	+33 47 33.0	9 0288	9.9187
10 33 5.7	5	15 . 3	—0 53.54	+4 19.8	3 9 55.68	+33 47 27.6		
13 8 57 48.5	6	10 . 2	+2 4.45	+1 10.9	3 1 26.64	+33 22 16.4	n8.8954	9.9346

Mean Places for 1890.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	s	
1	4 19 57.12	+3.81	+35 8 0.0	+ 9.9	Bonn VI. +35° 870
2	3 44 30.67	+3.75	+34 47 47.2	+13.9	" +34° 748
3	3 16 46.43	+3.61	+34 1 39.6	+16.5	Weisse's Bessel III, 303
4	3 11 50.67	+3.59	+33 49 10.6	+17.0	" " 203
5	3 10 45.64	+3.58	+33 42 50.8	+17.0	" " 178
6	2 59 18.66	+3.53	+33 20 47.7	+17.8	" " 1373

FILAR-MICROMETER OBSERVATIONS OF COMET *e* 1890 (*ZONA, Nov. 15*).

MADE WITH THE 12-INCH EQUATORIAL OF THE LICK OBSERVATORY,

BY E. E. BARNARD.

1890 Mt. Hamilton M.T.		No. Comp.	☄—*		☄'s apparent		log *p*Δ	
			Δα	Δδ	α	δ	for α	for δ
	h m s		m s	′ ″	h m s	° ′ ″		
Nov. 30	8 53 50	18 , 6	+0 22.10	—4 23.3	4 6 39.23	+35 7 28.0	*n*9.539	0.076

Mean Place for 1890.0 of Comparison-Star.

α	Red. to app. place	δ	Red. to app. place	Authority
h m s	s	° ′ ″	″	
4 6 13.01	+3.82	+35 11 39.8	+11.5	W.B. IV 48

ELLIPTIC ELEMENTS OF COMET 1890 *f* (*SPITALER*).

BY REV. G. M. SEARLE.

The observations of Nov. 16 and Dec. 4, made in Europe, together with those at Mt. Hamilton Dec. 6 and 7, seeming to furnish sufficient material for an approximate orbit of this comet, a parabola was computed from those of Nov. 16 and Dec. 7, using a ratio of the geocentric distances obtained as usual from the middle place and time of Dec. 4. The following elements resulted from the observations corrected approximately for parallax and aberration:

$$
\begin{aligned}
T &= 1891 \text{ Jan. } 5.6724 \text{ Gr. M.T.}\\
\Omega &= 62^\circ\ 59'\ 17'' \\
\omega &= 26\ \ 19\ \ 13 \\
i &= 33\ \ 16\ \ 37
\end{aligned}
\Bigg\}\ 1890.0
$$

$$\log q = 0.488416$$

On comparing these, however, with the places of Dec. 4 and 7, the following somewhat startling discordances were found; (O—C):

	Δλ	Δβ
	′ ″	′ ″
Dec. 4	+1 35	+0 54
6	+4 13	+2 36

and indeed, on determining the points of intersection of the lines of observation with the plane of the supposed orbit, it appeared that these points actually lay in a curve *convex* towards the sun.

It appeared certain that this could only be remedied by assuming shorter geocentric distances; but as distances materially shorter were quite irreconcilable with parabolic motion, the calculation was made from Nov. 16, Dec. 4 and 7, without any assumption as to eccentricity. The following decidedly different orbit resulted:

$$
\begin{aligned}
T &= 1890 \text{ Sept. } 30.3947 \text{ Gr. M.T.}\\
\Omega &= 49^\circ\ 22'\ 56'' \\
\omega &= 359\ \ \ 5\ \ 44 \\
i &= 45\ \ 53\ \ 58
\end{aligned}
\Bigg\}\ 1890.0
$$

$$
\begin{aligned}
\log q &= 0.287878\\
\varphi &= 40^\circ\ 4'\ 7''\\
\log a &= 0.736067\\
\log \mu &= 2.445907\\
\text{Period} &= 4642 \text{ days, or } 12^y.71.
\end{aligned}
$$

The residuals for the middle place, Dec. 4, were now, (O—C) Δλ = +1″, Δβ = 0″; for that of Dec. 6, +23″ and +9″.

These elements are still of course necessarily quite rough, as the intervals of time are not favorable for accuracy; but it would seem probable that the period is such as to place this comet among those subject to special perturbation by *Saturn*, and possibly brought into our system by that planet. The aphelion distance of the comet from these elements is 8.9514, and it occurs near the descending node; the mean distance of *Saturn* is about 0.6 greater.

The following are the coordinate equations, for mean equator and equinox, for 1890.0:

$$
\begin{aligned}
x &= [9.990401]\ r \sin(v + 137^\circ\ 22'\ 42'')\\
y &= [9.923001]\ r \sin(v + \ \ 55\ \ 20\ \ 32)\\
z &= [9.766876]\ r \sin(v + \ \ 30\ \ 12\ \ 40)
\end{aligned}
$$

For 1891.0 we have

$$
\begin{aligned}
x &= [9.990397]\ r \sin(v + 137^\circ\ 23'\ \ 4'')\\
y &= [9.923018]\ r \sin(v + \ \ 55\ \ 21\ \ 26)\\
z &= [9.766853]\ r \sin(v + \ \ 30\ \ 13\ \ 12)
\end{aligned}
$$

EPHEMERIS FOR GREENWICH MIDNIGHT.

Gr. M.T.		App. α	App. δ	log Δ	Br
		h m s	° ′		
1890 Dec.	24.5	4 58 42	+39 57.6	0.0686	0.76
	28.5	56 19	40 14.0	0.0794	0.71
1891 Jan.	1.5	54 30	40 26.6	0.0911	0.66
	5.5	53 10	40 35.6	0.1037	0.61
	9.5	52 26	40 41.6	0.1170	0.57
	13.5	52 18	40 45.0	0.1308	0.53
	17.5	4 52 48	+40 46.4	0.1451	0.48

EPHEMERIS OF VARIABLES OF THE *ALGOL*-TYPE.

Approximate Greenwich M.T., 1891.

In the following ephemeris the star *S Antliae* is not included, for the reason stated on page 91 (no. 228), where a separate ephemeris for it will be found covering the present season of its visibility. For the benefit of those who desire to participate in the exceedingly important work of observation of this class of stars, reference is made to Vol. VII, 187, where all necessary particulars are given for the purpose, with lists of comparison-stars, or references to places in the Journal where they may be found, except for *S Antliae*, discovered since that article was prepared, and the comparison-stars for which are given in Vol. IX, 181.

January	d	h	January	d	h	February	d	h	February	d	h	March	d	h
U Cephei	1	8	Algol	19	18	*R* Can. Maj.	6	18	*Y* Cygni	26	13	Algol	12	9
R Can. Maj.	1	19	*R* Can. Maj.	20	17	*U* Cephei	7	18	*U* Coronae	26	14	*Y* Cygni	13	12
U Coronae	2	8	*U* Cephei	21	7	δ Librae	7	20	*U* Cephei	27	16	*U* Cephei	14	15
Algol	2	13	*Y* Cygni	21	14	*Y* Cygni	8	14	δ Librae	28	19	δ Librae	14	18
R Can. Maj.	2	13	Algol	22	15	Algol	8	20	Algol	28	21	*U* Coronae	15	20
Y Cygni	3	15	*S* Cancri	23	4	*S* Cancri	11	3				*U* Ophiuchi	15	22
R Can. Maj.	3	16	*U* Cephei	23	19	*Y* Cygni	11	13	March			*Y* Cygni	16	12
U Cephei	3	20	*Y* Cygni	24	14	Algol	11	16	*R* Can. Maj.	1	11	*U* Ophiuchi	16	18
S Cancri	4	5	Algol	25	12	*R* Can. Maj.	12	10	*Y* Cygni	1	13	*R* Can. Maj.	17	9
R Can. Maj.	4	19	*U* Cephei	26	7	*U* Cephei	12	17	*S* Cancri	2	3	*R* Can. Maj.	18	12
Algol	5	10	*R* Can. Maj.	26	9	*U* Coronae	12	18	λ Tauri	2	10	*Y* Cygni	19	12
U Coronae	5	19	*U* Coronae	26	12	*R* Can. Maj.	13	11	*R* Can. Maj.	2	15	*U* Cephei	19	15
U Cephei	6	8	*R* Can. Maj.	27	13	Algol	14	13	*R* Can. Maj.	3	16	*R* Can. Maj.	19	16
Y Cygni	6	14	*Y* Cygni	27	14	*Y* Cygni	14	13	Algol	3	18	*S* Cancri	21	2
Algol	8	7	Algol	28	8	λ Tauri	14	15	*Y* Cygni	4	13	δ Librae	21	18
U Cephei	8	20	*R* Can. Maj.	28	16	*R* Can. Maj.	14	17	*U* Cephei	4	16	*U* Ophiuchi	21	19
Y Cygni	9	14	*U* Cephei	28	18	δ Librae	14	20	*U* Coronae	5	12	*Y* Cygni	22	12
R Can. Maj.	10	12	*Y* Cygni	30	14	Algol	17	10	*U* Ophiuchi	5	20	*U* Ophiuchi	22	15
U Cephei	11	8	Algol	31	5	*Y* Cygni	17	13	λ Tauri	6	9	*U* Coronae	22	18
R Can. Maj.	11	15	*U* Cephei	31	6	*U* Cephei	17	17	Algol	6	15	Algol	23	20
Y Cygni	12	14	δ Librae	31	21	λ Tauri	18	13	*U* Ophiuchi	6	17	*U* Cephei	24	15
U Coronae	12	17				*U* Coronae	19	16	*Y* Cygni	7	13	*R* Can. Maj.	25	8
R Can. Maj.	12	18	February.			Algol	20	7	δ Librae	7	18	*Y* Cygni	25	12
S Cancri	13	16	*S* Cancri	1	16	*R* Can. Maj.	20	9	*U* Coronae	8	22	*R* Can. Maj.	26	11
U Cephei	13	19	*U* Coronae	2	10	*Y* Cygni	20	13	*R* Can. Maj.	9	10	Algol	26	17
Y Cygni	15	14	*Y* Cygni	2	14	*S* Cancri	20	15	Algol	9	12	*U* Ophiuchi	26	19
U Cephei	16	7	*U* Cephei	2	18	*R* Can. Maj.	21	12	*U* Cephei	9	16	*R* Can. Maj.	27	14
Algol	16	21	*R* Can. Maj.	3	8	δ Librae	21	19	*Y* Cygni	10	13	*U* Ophiuchi	27	16
R Can. Maj.	18	11	*R* Can. Maj.	4	12	λ Tauri	22	12	*R* Can. Maj.	10	13	*Y* Cygni	28	12
Y Cygni	18	14	*U* Cephei	5	6	*R* Can. Maj.	22	16	*U* Ophiuchi	10	21	δ Librae	28	18
U Cephei	18	19	*Y* Cygni	5	13	*U* Cephei	22	17	*S* Cancri	11	14	Algol	29	14
R Can. Maj.	19	11	*R* Can. Maj.	5	15	*Y* Cygni	23	13	*R* Can. Maj.	11	17	*U* Cephei	29	14
U Coronae	19	11	*U* Coronae	5	21	λ Tauri	26	11	*U* Ophiuchi	11	17	*U* Coronae	29	15

CORRIGENDA IN No. 231.

Page 115, col. 2, line 26, *for* different *put* differential.
col. 2, line 12 and 4 from below, *for* μ *put* u.
Page 117, col. 1, last table, 4th heading, *for* Maxima *put* Minima.
Page 118, col. 2, line 13 from below, *for* Nov. 22.02000, *put* Nov. 23.02000.

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ON THE REDUCTION OF ASTRONOMICAL PHOTOGRAPHIC MEASURES,

By HAROLD JACOBY, B.A

The researches of various astronomers have shown that it is possible to make micrometric observations of the highest precision by means of photography. It is the object of the present paper to develop a method of reduction for observations of this kind.

Let us suppose that the photograph has been measured with a machine which determines the position of each star on the plate by means of two rectangular coordinates. I shall assume:

I. That proper corrections have been applied to the measures to allow for distortion of the film during development, or proper precautions taken to prevent the occurrence of such distortion.

II. That the plate, when mounted in the telescope, was perpendicular to a line drawn through the object-glass normally to all its surfaces.

III. That the point where such a line pierces the plate is known.

Let us take the point defined under III as the origin of coordinates for the measurement of the plate; and it may, perhaps, assist our ideas to look upon the plate as a tangent plane to a sphere whose radius r is equal to the equivalent focal length of the object-glass.

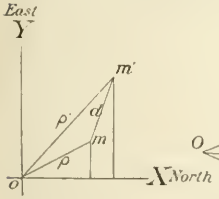

FIG. 1.

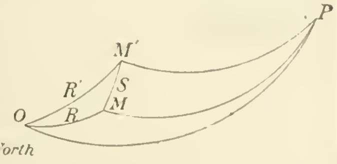

FIG. 2.

Now, in Fig. 1, which represents a portion of the sensitized surface, let o be the origin, and m, m' two star images; and in Fig. 2, which represents a portion of the celestial sphere, let O be the point at which the telescope is aimed, M and M' the two stars, and P the celestial pole. Then the point O will correspond to the point o, and the line which is normal to all the surfaces of the object-glass will pass through O and o. We shall "orient" the plate by making the positive axis of X correspond to the direction of zero position angle from the point O on the sky. The positive axis of Y on the plate will then correspond to the direction of position angle 90° from the point O on the sky. And the position angle of any star from O will be equal to the angle between the axis of X and a line joining the star-image on the plate with the origin o. Now, let us assume as the unit of all linear measures, one division of the scale of the measuring machine, and let

P, P' be the position angles of M and M' from the point O;
$x, y; x', y'$, the coordinates of m and m' on the plate;

ρ, ρ'	the linear distances of m and m' from o in Fig. 1;
R, R'	the angular distances of M and M' from O in Fig. 2;
$B_,$	the spherical angle OMM', Fig. 2;
$B_{\prime}$	the plane angle omm', Fig. 1;
r	the equivalent focal length of the object-glass;
s	the angular distance MM', Fig. 2;
d	the linear distance mm', Fig. 1;

we shall have:

$$\rho \sin P = y \qquad \rho' \sin P' = y' \qquad (1)$$
$$\rho \cos P = x \qquad \rho' \cos P' = x'$$

and from the triangle OMM', Fig. 2.

$$\tan B_, = \frac{\sin(P'-P)}{\sin R \cot R' - \cos R \cos(P'-P)}$$

and from the triangle omm', Fig. 1,

$$\tan B_{\prime} = \frac{\rho' \sin(P'-P)}{\rho - \rho' \cos(P'-P)}$$

But

$$\rho = r \tan R \qquad \rho' = r \tan R'$$

$$\therefore \tan B_{\prime} = \frac{\sin(P'-P) \cos R}{\sin R \cot R' - \cos R \cos(P'-P)} = \cos R \tan B_,$$

or, developing into series

$$B_, - B_{\prime} = \tan^2 \tfrac{1}{2} R \sin 2 B_{\prime} + \tfrac{1}{2} \tan^4 \tfrac{1}{2} R \sin 4 B_{\prime} + \ldots.$$

the first term of this series will always suffice, and if we put

$$\eta = B_s - B_p$$

we shall have,

$$(2) \qquad \eta = \tfrac{1}{2}\frac{\rho^2}{r^2}\sin B_p \cos B_p$$

Again, we have,

$$\sin s = \frac{\sin(P'-P)\sin R'}{\sin B_s}$$

$$d = \frac{\rho' \sin(P'-P)}{\sin B_p} = \frac{r \sin R' \sin(P'-P)}{\cos R' \sin B_p}$$

so that

$$\sin s = \frac{d \cos R'}{r} \frac{\sin B_p}{\sin(B_p+\eta)}$$

or, developing, and remembering that η is very small,

$$\sin s = \frac{d\cos R'}{r(1+\eta \cot B_p)} = \frac{d \cos R'}{r\left(1+\frac{1}{2}\frac{\rho^2}{r^2}\cos^2 B_p\right)}$$

But

$$\cos R' = \frac{1}{\sqrt{1+\tan^2 R'}} = \frac{1}{\sqrt{1+\frac{\rho'^2}{r^2}}} = 1 - \tfrac{1}{2}\frac{\rho'^2}{r^2} + \ . \ . \ .$$

Hence,

$$\sin s = \frac{d}{r\left(1+\frac{1}{2}\frac{\rho^2}{r^2}\cos^2 B_p\right)} - \tfrac{1}{2}\frac{\rho'^2}{r^2}\frac{d}{r\left(1+\frac{1}{2}\frac{\rho^2}{r^2}\cos^2 B_p\right)}$$

$$= \frac{d}{r}\left(1-\tfrac{1}{2}\frac{\rho^2}{r^2}\cos^2 B_p - \tfrac{1}{2}\frac{\rho'^2}{r^2}\right)$$

or,

$$(3) \qquad s = \frac{d}{r} - \tfrac{1}{2}\frac{d}{r^3}\rho^2\cos^2 B_p - \tfrac{1}{2}\frac{d}{r^3}\rho'^2 + \tfrac{1}{6}\frac{d}{r^3}d^2$$

Now B_p is the sum of the angle P, and the supplement of the inclination of the line $m\,m'$ to the axis of X; so that if we introduce Q by means of

$$(4) \qquad \begin{cases} d \sin Q = y' - y \\ d \cos Q = x' - x \end{cases}$$

we have

$$(5) \qquad B_p = P - Q + 180°$$

and consequently

$$B_s = P - Q + \eta + 180°$$

Now we have,

$$(6) \qquad R = \tan^{-1}\frac{\rho}{r} = \frac{\rho}{r} - \tfrac{1}{3}\frac{\rho^3}{r^3} + \ . \ . \ .$$

The position-angle of the line $O\,M$ at O is P, and the position-angle of the same line at M may be found by adding the Besselian correction

$$(7) \qquad \gamma = R \tan\delta \sin P + \tfrac{1}{2} R^2 \sin P \cos P\,(1+2\tan^2\delta)$$

where δ is the declination corresponding to the center of the plate. And finally, the position-angle of the line $M\,M'$ at the point M will be

$$(8) \qquad p = 180° - B_s + P + \gamma = Q + \gamma - \eta$$

I shall now show how the above formulas may be employed. If two or more "standard stars," whose positions on the sky are well determined, have been impressed on the plate, we can derive the constants of reduction from the rectangular coordinates of the images of the standard stars. But first we must calculate s and p for the standard stars.

Let α, α' be the known right-ascensions of the stars,
δ, δ' " " declinations " "

and let p be counted from 0° to 360° in the direction N.E.S.W., then we have

$$\left.\begin{aligned} \sin\tfrac{1}{2}s \sin p_0 &= \cos\tfrac{1}{2}(\delta'+\delta)\sin\tfrac{1}{2}(\alpha'-\alpha) \\ \sin\tfrac{1}{2}s\cos p_0 &= \sin\tfrac{1}{2}(\delta'-\delta)\cos\tfrac{1}{2}(\alpha'-\alpha) \end{aligned}\right\} \qquad (9)$$

from which to obtain s and p_0. This p_0 is the mean of the values of the position-angles at the two stars. It must be reduced to the position-angle p, at the star to which α and δ belong, by means of the formula,

$$p = p_0 - \tfrac{1}{2}s\tan\tfrac{1}{2}(\delta+\delta')\sin p_0 \qquad (10)$$
$$+\tfrac{1}{16}s^3\sin^2 1''\sin p_0\cos^2 p_0\tan\tfrac{1}{2}(\delta+\delta')\left[1+2\tan^2\tfrac{1}{2}(\delta+\delta')\right]$$

which gives the correction to p_0 in seconds of arc, and in which the last term will rarely be appreciable. The values of s and p so obtained are true values. They must be turned into apparent values by applying the usual corrections for refraction, precession, etc., before being used in what follows.

I shall assemble the necessary formulae, letting (x, y), (x', y') be the coordinates of any two standard stars, and also making a few simplifications.

We get,

from eq. (1) $\qquad \rho\sin P = y \qquad \rho'\sin P' = y'$
$\qquad\qquad\qquad \rho\cos P = x \qquad \rho'\cos P' = x'$

from eq. (4) and (5) $\qquad d\sin Q = y' - y \qquad B_p = P - Q$
$\qquad\qquad\qquad d\cos Q = x' - x$

from eq. (3) $\qquad r_1 = \frac{d}{s}$ cosec 1'' $\qquad$ (where s is in seconds of arc), which gives an approximate value of r, and

$$r = r_1 - \tfrac{1}{2}\frac{d}{r_1^2}\frac{\rho^2}{s}\cos^2 B_p \operatorname{cosec} 1'' - \tfrac{1}{2}\frac{d}{r_1^2}\frac{\rho'^2}{s}\operatorname{cosec} 1''$$
$$+\tfrac{1}{6}\frac{d}{r_1^2}\frac{d^2}{s}\operatorname{cosec} 1''$$

which gives the value of the required equivalent focal length for the plate under discussion. To obtain the error of orientation, we have

from eq. (2)

$\eta = \frac{1}{2}\frac{\rho^2}{r}\sin B_p\cos B_p$ cosec 1'', which gives η in seconds.

from eq. (6)

$R = \frac{\rho}{r}$ cosec 1'' $- \frac{1}{3}\frac{\rho^3}{r^3}$ cosec 1'', which gives R in seconds,

from eq. (7)

$\gamma = R\tan\delta\sin P + \frac{1}{2}R\sin P\cos P(1+2\tan^2\delta)\sin 1''$, which gives γ in seconds, and in which δ is the declination of the center of the plate. Finally, the correction for orientation required by the values of P and Q obtained from equations (1) and (4) will be, from equation (8)

$$\epsilon = p - Q - \gamma + \eta$$

If v be large it may be necessary to recompute γ, and thus get a new value of v. But no matter how large v may be, it will not affect the value obtained for r. If there are more than two standard stars, we can compute values of r and v from other pairs, and employ a mean value.

If the orientation of the plate is to depend upon a "trail," instead of a pair of standard stars, we may still employ the above formulas, if we put $\delta = \delta'$.

Equations (9) then show that $p_0 = 270°$. So we have, for the determination of v, r being of course supposed otherwise known: (11)

$$d \sin Q = y' - y$$
$$d \cos Q = x' - x$$
$$\rho \sin P = y$$
$$\rho \cos P = x$$
$$\rho' \sin P = y'$$
$$\rho' \cos P = x'$$
$$B_p = P - Q$$
$$s = \frac{d}{r} \operatorname{cosec} 1'' - \tfrac{1}{2} \frac{d}{r^3} \rho^2 \cos^2 B_p \operatorname{cosec} 1'' - \tfrac{1}{2} \frac{d}{r^3} \rho'^2 \operatorname{cosec} 1'' + \tfrac{1}{6} \frac{d}{r^3} d^2 \operatorname{cosec} 1''$$
$$\eta = \tfrac{1}{2} \frac{\rho^2}{r^2} \sin B_p \cos B_p \operatorname{cosec} 1''$$
$$R = \frac{\rho}{r} \operatorname{cosec} 1'' - \tfrac{1}{3} \frac{\rho^3}{r^3} \operatorname{cosec} 1''$$
$$\gamma = R \tan \delta \sin P + \tfrac{1}{2} R^2 \sin P \cos P (1 + 2 \tan^2 \delta) \sin 1''$$

where δ is the declination of the center of the plate

$$p = 270° + \tfrac{1}{2} s \tan \tfrac{1}{2}(\delta + \delta')$$
$$v = p - Q - \gamma + \eta$$

and if the trail belongs to a central star these become,

$$(12) \quad \begin{cases} d \sin Q = y' \\ d \cos Q = x' \\ s = \dfrac{d}{r} \operatorname{cosec} 1'' - \tfrac{1}{3} \dfrac{d^3}{r^3} \operatorname{cosec} 1'' \\ p = 270° + \tfrac{1}{2} s \tan \tfrac{1}{2}(\delta + \delta') \\ v = p - Q \end{cases}$$

Having obtained the constants r and v, the most convenient method is to determine the position-angle and distance of every star on the plate from the point O. These quantities must then be converted into differences of R.A. and δ, giving a $\Delta\alpha$ and $\Delta\delta$ for each star. Then the $\Delta\alpha$ and $\Delta\delta$ of the standard stars will make known the R.A. and δ corresponding to the point O, and the $\Delta\alpha$ and $\Delta\delta$ of any star being then applied to the R.A. and δ of the point O, will of course give the position of the star. The convenience of referring all the stars to the point O, instead of referring them directly to one or more of the standard stars, arises from the fact that our formulas become much simpler in the former case. For if one of the points under consideration is at the origin, we may put

$$x = o,\ y = o,\ \rho = o,\ d = \rho',\ \eta = o,\ \gamma = o.$$

Eq. (3) then becomes

$$s = \frac{d}{r} \operatorname{cosec} 1'' - \tfrac{1}{3} \frac{d^3}{r^3} \operatorname{cosec} 1''$$

which gives s in seconds of arc (see foot-note a), and eq. (8) gives

$$p = Q + v$$

d and Q being derived from

$$d \sin Q = y'$$
$$d \cos Q = x'$$

It should be observed that the position-angle p so obtained corresponds to the point O on the sky; and in order to deduce $\Delta\alpha$ and $\Delta\delta$, it is necessary to add to p the Besselian correction,

$$\gamma' = \tfrac{1}{2} s \tan \delta \sin p + \tfrac{1}{4} s^2 \sin p \cos p (1 + 2 \tan^2 \delta) \sin 1''$$

where δ is the declination of the point O, and constant for all stars on the plate. The formula gives γ' at once in seconds of arc. This reduction having been applied, we have the mean of the position-angles at the two stars. Further corrections having been applied for refraction, etc., we can at once compute $\Delta\alpha$ and $\Delta\delta$ for each star, with reference to the point O. And, as above indicated, the R.A. and δ of the point O being derived from the $\Delta\alpha$ and $\Delta\delta$ of the standard stars, we get, finally, the true α and δ of the unknown stars.

It is of course needless to remark, that if the plate has been measured with a machine giving the polar coordinates of any star at the point o, we shall have the values of d and Q at once from the machine. So that the final formulas, namely,

$$d \sin Q = y'$$
$$d \cos Q = x'$$
$$s = \frac{d}{r} \operatorname{cosec} 1'' - \tfrac{1}{3} \frac{d^3}{r^3} \operatorname{cosec} 1''$$
$$p = Q + v$$

become, simply

$$\left.\begin{aligned} s &= \frac{d}{r} \operatorname{cosec} 1'' - \tfrac{1}{3} \frac{d^3}{r^3} \operatorname{cosec} 1'' \\ p &= Q + v \end{aligned}\right\}$$

but in either case, we must apply to p the correction

$$\gamma' = \tfrac{1}{2} s \tan \delta \sin p + \tfrac{1}{4} s^2 \sin p \cos p (1 + 2 \tan^2 \delta) \sin 1''$$

before computing $\Delta\alpha$ and $\Delta\delta$.

Columbia College, 1890 *December*.

(a) This agrees with the equation given by Dr. B. A. Gould in *Natl. Acad. Sc.* Vol. IV, Third Memoir, after the correction of a typographical error in the latter.

NOTE ON THE ELEMENTS OF *Y CYGNI*,

BY PAUL S. YENDELL.

The watch on *Y Cygni* was so much broken up by unfavorable weather during the past season, that the first minimum of the star observed by myself was obtained October 11; three others were afterwards secured, when, the star being so very low at its minimum phase as to render observations of very questionable value, work upon it was dropped for the season.

The minima observed were as follows:

E		h m		w
936	1890 Oct. 11	12 9	Boston M.T.	4
952	Nov. 4	12 8		3
958	13	11 25		3
962	19	10 41		½

Upon comparing these observations with **Chandler**'s elements, published in the Supplement to his Catalogue (*A.J.*, IX, 186), the residuals indicated that the star's period was then very nearly at its mean value, as represented by these elements, and it seemed a fair opportunity for attempting a solution of the enigma offered by its anomalies during the past five years.

Forty-two minima, three of my own, obtained by the use of a mean light-curve, being omitted, were found available for the purpose, viz.: those published by **Chandler** and myself in this *Journal*, Vol. VIII, p. 131, and Vol. IX, pp. 92 and 166, together with my own, given above. Using as a basis **Chandler**'s elements above referred to, the residuals, upon being plotted, grouped themselves as follows: those for 1886 and 1890 about the line of computed minima; those of 1887 and 1889 all on the negative side; and those of 1888 on the positive side, thus strongly indicating a periodical change in the epoch of minimum.

Careful consideration of the mean epochs and residuals resulted in the adoption for trial of a sine-term, which proved to satisfy the observations as well as any which could be found. Although not satisfactory, and leaving still outstanding large residuals, it seems the best approximation possible under the circumstances, and until observations extending over a longer period are available for its amendment: an obscure indication of a secondary sine-term in the residuals for 1887 and 1888, is negatived by those of 1889, and was abandoned.

The fluctuations of the period from its mean value cover a span of about 610 of the star's periods, or nearly two years, in passing through all their features; and the elements finally adopted consist of **Chandler**'s above quoted, with the addition of the sine-term. They are as follows:

$$1886 \text{ Dec. } 9\ 11^h\ 14^m.5 \text{ G.M.T.} \quad +1^d\ 11^h\ 57^m\ 18^s\ E$$
$$-113^m \quad \sin 34'.8\ (E-15)$$

Dorchester, Mass., 1890 *December* 23.

The residuals resulting from the use of the above elements are compared with those from which the elements were deduced in the following table. The column O—C contains the original residuals, and that headed O—C′ those resulting from the use of the sine-term. The letters indicating the observers are C. for **Chandler**, S. for **Sawyer**, and Y. for myself.

E	O—C	O—C′	Wt.	Observers
	m	m		
0	— 17.0	—34.3	½	C
8	+ 0.6	— 7.75	1	C
12	— 1.1	— 4.76	1	C
16	+ 3.3	+ 4.48	2	C
22	— 1.0	+ 7.18	1	C
165	—129.4	—16.4	½	S
167	— 93.9	+19.6	1	S
169	—103.5	+ 9.5	½	S
173	—132.6	—19.6	1	S
183	— 96.1	+15.4	½	S
189	— 80.1	+29.0	1	C
205	—108.4	— 3.7	3	C
207	—102.2	+ 1.3	3	C
209	—106.0	— 2.8	1	C
217	—114.3	—15.3	1	C
221	—108.0	—10.0	3	C
390	+ 91.7	+17.0	5	C
418	+ 84.0	—11.3	2	C
428	+100.5	— 1.0	2	Y
440	+138.1	+25.0	2	Y
448[1]	+188.4	+80.0	2	Y
661	— 97.0	—67.7	2	C
681	— 77.0	—33.0	2	Y
687	— 38.0	+19.0	5	Y
695	— 26.1	+38.2	5	Y
695	— 92.6	—28.0	3	C
697	— 73.4	— 6.9	5	Y
697	—106.4	—39.9	3	C
701	— 83.1	—12.6	1	Y
709	—112.1	—34.9	5	Y
709[2]	—109.1	—31.9	5	C
715	— 83.2	— 1.2	3	Y
715[2]	— 79.2	+ 2.8	3	C
717	— 62.6	+20.9	4	Y
717[2]	— 67.1	+15.4	4	C
725	—113.6	—24.0	5	Y
737	—152.8	—55.8	3	Y
741	—182.5	—82.5	2	Y
936	— 11.5	+ 0.8	4	Y
952	+ 39.0	+27.0	3	Y
958	+ 11.4	— 2.4	3	Y
962[3]	— 37.6	—56.2	1	Y

---

[1] Of very doubtful value. Only a single comparison-star was used, and the star was very low at minimum. Weight was assigned by **Chandler**.

[2] Weight assumed by myself.

[3] Very doubtful. Star very low at minimum.

ON THE PERIOD OF 2100 *U ORIONIS*.

BY S. C. CHANDLER

In the *Monthly Notices*, R. A. S., for June 1890, Mr. Gore has found, by a least-square solution, 373.47 days as the period of this star. I would courteously call attention to the fact that this value is so highly improbable as to be practically an impossible one. According to the elements given, the star, from its known light-variations near maximum, would have been about 6^{M} and 7^{M}, respectively, on 1850 Dec. 30, and 1851 Nov. 24, and could not have been passed over at Markree. It would likewise have been about 8^{M} on 1853 Nov. 6, and 1855 Feb. 18, and certainly observed, if at that brightness, by Schönfeld in the DM. zones on those dates; on the latter of which, indeed, the variable was probably the star actually observed, but only as $9^{\mathrm{M}}.5$. These elements also give it as 8^{M} on 1857 Feb. 9, when Krueger, in a revision-zone with the five-foot telescope, failed to see it, although recording the two small companions only 3^{s} following. The further conflict with Lalande's and Bessel's non-observation of the star on 1797 Feb. 17, and 1826 March 3, can not perhaps be similarly insisted upon, as it possesses little significance.

It may be stated with confidence that the above data allow us to rule out all assumptions of period between 361 and 367 days, and over 371.5 days. As Mr. Gore also omits from his collection of observed maxima about one-third of those which have been published, it may be worth while to give here the full data, and their comparison with my elements in *A.J.* Vol. IX, p. 186, namely 1885 Dec. 7.0 + $371^{\mathrm{d}}.0$ *E*. These elements, it may be mentioned, assign dates of maximum from three to five months distant from all the Markree and Bonn dates above given, and also from that of Lalande, and two months from that of Bessel; and hence are consistent with all.

Ep.	Obs'd maximum	O—C	Obs.
0	1885 Dec. 13:	+ 6^{d}:	Gore
1	1886 Dec. 11	— 2	Gore
"	16	+ 3	Markwick
"	13	0	Sawyer
"	9	— 4	Parkhurst
2	1887 Dec. 14	— 5	Sawyer
"	16	— 3	Markwick
"	30	+11	Gore
3	1888 Dec. 29	+ 5	Markwick
"	27.5	+ 3.5	Yendell
"	26	+ 2	Sawyer
"	1889 Jan. 1	+ 8	Gore
4	1890 Jan. 6	+ 7	Sawyer
"	13	+14	Gore

The progression in the residuals (O—C) cannot be disposed of without using a period which violates the conditions above set forth. It perhaps reveals the presence of a periodical term, such as I have proved to exist in such a large proportion of the long-period stars that it may be regarded as inseparably associated with this type of variables.

Cambridge, 1890 *Dec.* 23.

OBSERVATIONS OF VARIABLE STARS IN 1890,

BY EDWIN F. SAWYER.

1. *R Scuti.*

On this star 32 observations were obtained, extending from June 7 to December 4. Series much broken, notably from June 18 to July 16, July 20 to August 2, and from November 16 to December 4. The charted observations permit the certain determination of one maximum and two minima. When first observed on June 7, *R* was evidently near a maximum; light = 17.7. The light slowly faded after June 18, and a bright minimum was reached August 18; light = 11.8. A slow and regular rise occurred, and a rather bright maximum was passed on September 27; light = 19.5. The light very rapidly faded after September 30, and a second and faint minimum was reached November 9; light = 6.2. This was followed by a rapid rise, and when last observed on December 4, *R* was very bright and evidently wearing another maximum; light = 18.1. The interval between the two minima was 83 days.

2. *R Coronae.*

This star was under observation from May 16 to November 16, 27 observations being secured. *R* was subject to several minor fluctuations of light during the year amounting to half a magnitude. When first observed on May 16, *R* was at about its normal brightness or midway between the stars DM. 32° 2621 and 30° 2682; or about $6^{\mathrm{M}}.4$. The light slowly increased, passing a maximum about July 3, when *R* was $6^{\mathrm{M}}.1$. After July 16, the light declined irregularly, pasing a minimum on September 8, *R* being $6^{\mathrm{M}}.6$. A rapid rise occurred and a second maximum was passed October 12, *R* being about $6^{\mathrm{M}}.2$. A decline followed after October 15, and continued up to the date of the last observation on November 16.

3. 36 (*U.A.*) *Ceti.*

This star was observed on 10 evenings, from September 18 to December 9 When first seen it was = 28 (*U.A.*) *Ceti* or $6^{M}.5$. The increase was rapid and uniform, a maximum being passed October 22, and the maximum brightness being 1 step > 18 (*U.A.*) *Ceti*, and 5 steps < 15 (*U.A.*) *Ceti* or $5^{M}.5$. The decrease was slow and regular; and when last observed on December 9 the star was = 10 (*U.A.*) *Ceti*, and 4 steps < 7 (*U.A.*) *Ceti* or $6^{M}.3$.

4. *g Herculis.*

The observations of this star extend from May 16 to November 16 and number 26. When first observed, on May 16, *g* was near a maximum. From May 20 the light suddenly declined and a rather faint minimum was passed about June 8. A sudden increase followed and a maximum was passed July 27. A second minimum was reached on September 3, followed by a rapid rise and an apparent constancy of light until the observations ended. The interval between the two minima was 83 days. The extent of fluctuation while under observation was about half a magnitude.

5. χ *Cygni.*

This star was observed from May 21 to September 19, the observations numbering 14. When first seen, on May 21, χ was 3 steps < DM. 33°3602 or about $7^{M}.2$. A very rapid and regular rise followed, a maximum being reached on June 20: the maximum brightness being 4 steps > DM. 29°3684, and 4 steps < DM. 34°3798 or $4^{M}.6$. The light faded very slowly and when last seen, χ was = DM 32°3578 or about $8^{M}.0$.

Brighton, Mass., 1890 *Dec.* 25.

ELEMENTS AND EPHEMERIS OF COMET *e* 1890 (ZONA).

BY W. W. CAMPBELL.

From the mean of the observations made at Cambridge, Mt. Hamilton and Columbia College on Nov. 18, and the Cambridge observations made on Nov. 28 and Dec. 15, I have obtained the following data:

$$T = \text{Gr. M.T. 1890 Aug. } 7^{d}.0933$$

$$\left.\begin{aligned} \omega &= 331^\circ\ 18'\ 42''.2 \\ \Omega &= 85\ \ 22\ \ 33\ .8 \\ i &= 154\ \ 18\ \ 52\ .2 \end{aligned}\right\}\ 1890.0$$

$$\log q = 0.311132$$

$$T = \text{Gr. M.T. 1890 Aug. } 7^{d}.0933$$

$$\left.\begin{aligned} \omega &= 331^\circ\ 18'\ 43''.3 \\ \Omega &= 85\ \ 23\ \ 25\ .0 \\ i &= 154\ \ 18\ \ 52\ .2 \end{aligned}\right\}\ 1891.0$$

$$\log q = 0.311132$$

Residuals (O—C), $\Delta\lambda' = -0''.3$, $\Delta\beta' = -6''.9$

CONSTANTS FOR THE EQUATOR, 1891.0

$$x = [9.955140]\ r \sin(336^\circ\ 25'\ 28''.7 + v)$$
$$y = [9.975488]\ r \sin(\ 75\ \ 57\ \ 24\ .3 + v)$$
$$z = [9.733725]\ r \sin(\ 18\ \ 24\ \ \ 2\ .6 + v)$$

EPHEMERIS FOR GREENWICH MEAN MIDNIGHT.

1891	App. α	App. δ	log *r*	log Δ	Br.
	h m s	° ′			
Jan. 4.5	1 57 59	+28 53.4	0.4313	0.3362	0.35
6.5	54 36	28 32.8			
8.5	51 31	28 13.6	0.4360	0.3573	0.32
10.5	48 43	27 55.7			
12.5	46 11	27 39.1	0.4407	0.3777	0.28
14.5	43 54	27 23.4			
Jan. 16.5	1 41 50	+27 8.8	0.4454	0.3975	0.25
18.5	39 58	26 55.2			
20.5	38 18	26 42.6	0.4500	0.4167	0.22
22.5	36 48	26 31.1			
24.5	35 29	26 20.7	0.4547	0.4349	0.20
26.5	31 19	26 11.2			
28.5	33 18	26 2.6	0.4594	0.4525	0.18
30.5	32 25	25 54.8			
Feb. 1.5	31 39	25 47.9	0.4640	0.4691	0.16
3.5	31 1	25 41.8			
5.5	30 29	25 36.5	0.4686	0.4850	0.15
7.5	30 3	25 31.8			
9.5	29 42	25 28.0	0.4732	0.5001	0.14
11.5	29 27	25 24.8			
13.5	29 17	25 22.3	0.4778	0.5143	0.13
15.5	29 12	25 20.3			
17.5	29 11	25 19.0	0.4824	0.5278	0.12
19.5	29 14	25 18.2			
21.5	29 21	25 18.0	0.4870	0.5406	0.11
23.5	29 31	25 18.2			
25.5	29 44	25 19.0	0.4915	0.5526	0.10
27.5	30 0	25 20.2			
Mar. 1.5	1 30 19	+25 22.0	0.4960	0.5639	0.09

I am indebted to Mr. W. J. HUSSEY for his kind assistance in computing a part of the ephemeris.

The residuals given above cannot be sensibly reduced, since $\Delta\lambda'$ changes very much more rapidly than $\Delta\beta'$.

The residuals for my preliminary orbit, distributed by the *Science Circular*, were $\Delta\lambda' = +0'.1$, $\Delta\beta' = 0'.0$.

Ann Arbor, 1891 *Jan.* 6.

GREENWICH MEAN TIME OF THE CONJUNCTION OF *JUPITER'S* SATELLITES RELATIVE TO *JUPITER'S* EQUATOR AS THEY MAY BE SEEN FROM THE EARTH IN JANUARY, 1891.

By Rev. A. FREEMAN, M.A., F.R.A.S.

It is desired to secure, if possible, that no occultation of one of *Jupiter's* satellites by another shall be missed, from want of directing a sufficiently powerful instrument to the planet at this critical time, when the earth is so nearly in the plane of *Jupiter's* equator. Actual observations of these occultation-phenomena are comparatively rare, although, we might expect them about once in six years. I think they would have a value to correct the nodes and inclinations assigned to the orbits of the satellites relatively to *Jupiter's* equator, and to determine the true position of the plane of that equator, if regularly watched for.

With a parallel-wire micrometer in the hands of an astronomer accustomed to double-star measurement very accurate work may be done. My own opinion is, that at all times these conjunctions would be vastly superior to transits or occultations for determining the true motions of the satellites. Whether they would be superior to eclipses or to passages of shadows across the central meridian of *Jupiter* I cannot say. A point in favor of shadow-phenomena is, that the position of the shadow relative to the apparent center of *Jupiter's* disc can be assigned by micrometric measures with some precision. It ought to be remembered that *Jupiter's* geocentric radius lies on his equator on January 9, 1891.

Time d h m	Satellite	Distance	Position	Time d h m	Satellite	Distance	Position
1 16 2	III II	9.1	E†	11 1 55	I II	5.6	W†*
2 12 47	III I	1.25	W	11 18 13	I II	5.6	E†
2 16 32	III IV	3.2	W	12 11 14	IV III	9.4	W
2 17 19	II IV	3.0	W	12 18 23	I III	5.9	W
3 0 2	III II	7.0	W‡*	13 16 38	I III	5.8	E
4 14 29	I II	1.5	E‡	15 9 0	I II	5.77	E†
5 14 15	I III	5.6	W	16 14 58	II III	2.5	E†
6 9 9	I III	4.5	E‡	17 13 57	III II	9.4	W†
8 0 22	I II	2.25	E†*	18 10 40	IV IV	14.8	W
8 20 45	III II	9.2	E†	18 10 51	I II	1.7	W†
9 18 51	III II	2.1	W†				

The satellite nearest the earth is named first. Apparent distances from the center of *Jupiter* are given in multiples of his equatorial radius. E and W mark the position of the satellites relative to the center of *Jupiter*. (*) Shows that the planet is above the horizon of Greenwich; (†) That the satellites appear to move in the same direction with relatively star motion; (‡) Denotes a very close approach to a conjunction.

To convert into Washington M.T. deduct 5h 8m from each time.

Marston Rectory, Sittingbourne, England.

NOTE ON OBSERVATION OF SPITALER'S COMET *f* 1890.

By O. C. WENDELL.

Communicated by Professor EDWARD C. PICKERING, Director.

From a subsequent examination of the region, the object observed for Spitaler's comet on Dec. 22, and published in the *Astronomical Journal*, Vol. X. p. 123, is found to be a faint star. As was mentioned at the time of publication, the rather low altitude and bad atmospheric conditions together with the faintness of the comet, prevented its positive identification at time of observation

Harvard College Observatory, 1891 *Jan.* 6.

FILAR-MICROMETER OBSERVATIONS OF COMET *d* 1890 (*D'ARREST*).

MADE WITH THE 26-INCH EQUATORIAL OF THE LEANDER MCCORMICK OBSERVATORY OF THE UNIVERSITY OF VIRGINIA.

(Communicated by the Director.)

1890 Local M.T.	✳	No. Comp.	☉ – ✳ Δα	☉ – ✳ Δδ	☉'s apparent α	☉'s apparent δ	log pΔ		Obs.
d h m s			m s	′ ″	h m s	° ′ ″			
Dec. 10 7 1 12	1	4 , 3	+1 37.12	+0 3.2	23 10 24.75	−20 36 50.2	9.187	0.870	S
7 33 51	2	3 , 2	−0 22.51	−2 53.1	23 10 28.94	−20 36 22.9	9.343	0.862	S
8 2 24	1	3 , 2	+1 11.10	+0 12.1	23 10 31.11	−20 36 11.2	9.136	0.853	D
12 7 37 37	3	4 , 1	+1 38.16	+1 50.0	23 16 9.34	−20 1 53.0	9.363	0.858	D
13 7 56 49	1	1 , 3	+1 1.92	−6 20.0	23 19 1.60	−19 18 12.6	9.178	0.849	P

Mean Places for 1890.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	23 8 45.12	+1.89	—20 36 58.8	+5.4	Wash. Zones; α Mer. Circ.; δ, $\frac{1}{2}$(Mer. Circ. + Mural)
2	23 10 49.57	+1.89	—20 33 24.7	+5.4	Cincin. Zones, 3914
3	23 14 28.95	+1.91	—20 9 19.2	+5.8	Cincin. Zones, 3923
4	23 19 17.82	+1.92	—19 16 55.0	+6.0	Anonymous, compared with Cincin. Zones, 3934

S = Ormond Stone; D. = C. L. DeMott; P. = N. M. Parrish.

Dec. 10. Diffuse; slight nucleus.

Dec. 13. Haze; comet faint.

$* 4 - * 3931 = +1^{m}\ 20^{s}.07$ (4); $-4'\ 26''.4$ (1)

$* 3934 \quad \alpha = 23^{h}\ 17^{m}\ 57^{s}.75; \quad \delta = -19^{\circ}\ 42'\ 28''.6.$

NOTE ON COMET 1889 V (*BROOKS, 1889 July 6*),

By E. E. BARNARD.

On the morning of Dec. 21 I secured another observation of the Comet 1889 V, with the 36-inch equatorial. It was much easier to observe than on Nov. 21 and 22, though still very difficult. A good filar-micrometer position was obtained which will perhaps be correct to within one or two seconds of arc. Motion was apparent during the observations, as the comet was passing quite close to a 16-mag. star. It is possible that some of the other large telescopes may be able to deal with it now, hence this note. The comparison-star of this morning has to be observed, but the comet's position is close to Mr. Bellamy's ephemeris in *A. J.*, 230.

Mt. Hamilton, 1890 *Dec.* 21.

FILAR-MICROMETER OBSERVATION OF COMET 1889 V.

1890 Mt. Hamilton M.T.	No. Comp.	☄—* Δα	☄—* Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for α	log pΔ for δ
h m s		m s	′ ″	h m s	° ′ ″		
Dec. 20 16 46 26	3 , 5	—0 15.93	+1 31.7	8 54 10.41	+25 25 1.0	9.394	0.332

Mean Place for 1890.0 of Comparison-Star.

α	Red. to app. place	δ	Red. to app. place	Authority
h m s	s	° ′ ″	″	
8 54 22.75	+3.29	+25 23 45.2	—15.9	Comp. with B.B. 25° 2027

The star was measured direct with the micrometer in both coordinates.

Comet about 6″ or 8″ in diameter; extremely difficult, and between 16^{M} and 17^{M}; the limit of the 36-inch being assumed as about 17^{M}. The comparison-star is $9^{M}.7$.

Star —B.B. 25° 2027, $\Delta\alpha = -0^{m}\ 18^{s}.75$ (18), $\Delta\delta = -7'\ 59''.1$ (3).

I also measured the position of DM. 25° 2026.

DM. 25° 2026 —B.B. 25° 2027, $\Delta\alpha = -0^{m}\ 2^{s}.42$ (12), $\Delta\delta = -3'\ 20''.6$ (4),

whence the place for 1890 of DM. 25° 2026 is $\alpha = 8^{h}\ 54^{m}\ 39^{s}.08$, $\delta = +25^{\circ}\ 28'\ 23''.7$.

Mt. Hamilton, 1890 *Dec.* 24.

CORRIGENDUM.

No. 230, p. 111, in Mean Place of Comparison-Star, *for* $9^{h}\ 0^{m}\ 53^{s}.60 \left\{\begin{matrix}-2^{s}.37\\-2.40\end{matrix}\right.$ *put* $9^{h}\ 0^{m}\ 33^{s}.60 \left\{\begin{matrix}+2^{s}.37\\+2.40\end{matrix}\right.$.

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A STUDY OF THE DISCREPANCIES BETWEEN TABULAR AND OBSERVED SOLAR POSITIONS, 1800–1886.

BY ORRAY TAFT SHERMAN.

The application of the gravitational analysis answers the question how far the motion of the heavenly bodies can be explained as the effect of a force varying directly as the masses, and inversely as the square of the radius. If there are other effective causes, their result must be sought among the residuals. These residuals are extremely small, and are known to be affected by errors of various sorts, errors of observation, computation, instrumental condition, tabular reduction, etc., some systematic, some accidental. A single residual of the size to which we have long since been accustomed, could serve as a basis for no prediction. Yet in spite of the high perfection to which each branch of astronomical science has been brought, discrepancies of comparatively large amount do occur, and seem not to be avoidable. The question, therefore, presents itself whether a part of each residual may not represent an unrecognized source of disturbance. By gathering together as large a number of observations as may be, made under as many different conditions as possible, that part which is purely accidental may be approximately eliminated. By combining many systems, that part which is systematic may be rendered approximately constant. If then there be outside disturbing causes, either cumulative or varying periodically, their existence should in the course of time appear as errors far too large or too persistent to be considered the effect of residual imperfections. The answer to our question is transferred from a single residual to the combined statement of many thousand residuals. Our ability to read the oracle is a question of general information.

All the residuals of solar observations which I could obtain are therefore converted into latitude and longitude, and presented herewith. The results from a single observatory have appeared so far affected by unknown error as to be of very little weight. So it has not seemed that the discussion of the Greenwich series before eighteen hundred could add or subtract from the value of the result. Our study, therefore, commences with the beginning of the Paris series in eighteen hundred. The first eight years are conveniently referred to DELAMBRE's table of that date. Although their evidence is strictly in accord with that which we present, it has seemed too fragmentary for presentation.

In 1808, improved tables were adopted by the *Connaissance des Temps*, and in 1813 by the *Nautical Almanac*. From 1808 to 1833, we have referred everything to this table. From 1833 to 1856, everything is referred to CARLINI's corrected tables, which may be considered as practically DELAMBRE's table of 1808 corrected. From 1856 to 1886, everything is referred to LEVERRIER's table. It would seem that each of these periods was too short for the accumulation of any considerable error from deficient knowledge of planetary masses.

When we chart the series obtained as above, and given in detail in the tables appended, we find some very suggestive relations to the sunspot curve. The maxima and minima of the earliest series seem to happen when the value of the sunspot number is six. The second series presents two maxima which might belong to this series, and also presents a rapid rise at each sunspot minimum. In the third series this rapid rise at sunspot minimum is predominant, and there are three secondary maxima which might belong to the first series. We are thus led to seek a method of calculating the sunspot effect. Whatever the nature of the effect, we may consider it a variation of the solar constant k, — in excess, if the sunspot activity is greater than the mean activity to be ascribed to the tables; in default, if less. The increase of the true anomaly is proportional to the force; the disturbance on this motion is therefore proportional to the variation of the force during the time the sunspot is active. We should, therefore, in strictness form an integration of such effects by a study of the sunspot records. Whether the study of the magnetic records may not allow us to do so in the future is an open question. To-day such a study is practically *ultra vires*. We are, however, dealing with accumulated effects; and since the effect of each sunspot is extremely small, shall attain practical accuracy by dealing with the accumulated sunspot record. Unity in WOLF's sunspot series may be taken to represent a sunspot of mean efficiency, active during the whole year. If, then, p represent the effect of such a spot so acting, and Δ the sum of the excesses of the sunspot numbers above the mean aforesaid, the apparent correction to the tables at the instant is $p\Delta + C$, C being the apparent correction at the moment when Δ commences, the constant of integration as it were. Representing the values of the 1809–1833 series by such an expression, and determining p and C by simple methods, we find

$$p = +0''.0146 \quad C = \text{for } 1811, \quad +1''.76,$$

while the equivalent state of solar efficiency is Wolf's number 6. During the year 1812 the state of spot activity is one less than the mean; the calculated correction, therefore, sinks by the hundredth of a second, and becomes $+1''.75$. During the year 1813 the mean state of spot activity is 7 in excess, the sum A becomes 6, and the calculated correction $+1''.84$. During the year 1814 A becomes equal to 14, and the calculated correction $+1''.95$.

Apparent Corrections to Delambre's Corrected Table of 1806 (*Connaissance des Temps*).

Year	No. observatories	No. of observat'ns	Wolf's sunsp't number	Corr. to tabular longitude	Calculated sunspot effect	Residual
				″		″
1809	2	125	2	+0.63	+1.91	−1.28
1810	2	142	0	+2.65	+1.85	+0.80
1811	2	181	1	+1.65	+1.76	−0.11
1812	2	127	5	+0.27	+1.74	−1.47
1813	2	147	13	+2.12	+1.85	+0.27
1814	2	147	14	+2.89	+1.96	+0.93
1815	2	178	35	+2.69	+2.39	+0.30
1816	3	271	46	+2.98	+2.97	+0.01
1817	3	283	41	+3.09	+3.48	−0.39
1818	3	311	30	+3.88	+3.83	+0.05
1819	3	217	24	+3.89	+4.10	−0.21
1820	3	266	15	+4.92	+4.22	+0.70
1821	3	230	6	+4.40	+4.22	+0.18
1822	3	318	4	+4.40	+4.20	+0.20
1823	3	261	2	+4.55	+4.14	+0.41
1824	3	206	9	+3.06	+4.18	−1.12
1825	3	250	16	+3.89	+4.29	−0.40
1826	3	302	36	+5.12	+4.72	+0.40
1827	3	217	49	+4.42	+5.35	−0.93
1828	3	177	62	+6.11	+6.17	−0.05
1829	2	228	67	+4.09*	+7.06	−2.97
1830	2	228	71	+4.04*	+8.00	−3.96
1831	2	214	48	+8.56*	+8.62	−0.06
1832	2	247	28	+7.49*	+8.94	−1.45

* 1″.13 has been added to each of the last four numbers as a correction for the wanting observatory.

In the same way we have formed the remaining figures given in the sixth column. While we might have obtained a closer correspondence by the means of a more elaborate analysis, this seems sufficient to show that there exists a close correspondence between the observed and calculated values. The last four values of the series come from defective data, and though a correction is applied, are still not entitled to full weight. On the other hand, it is to be said that the sunspot is not the only cause of error. The commencement of the next series may indicate causes acting to diminish the correction in this.

Apparent Corrections in Longitude to Carlini's = Delambre's Corrected Tables of 1832.

Year	No. observatories	No. of observat'ns	Wolf's sunsp't number	Corr. to tabular longitude	Calculated sunspot effect — C	Residual — C
				″	″	″
1833	3	384	9	+0.83	0.83	0.00
1834	4	477	13	+2.32	0.17	+2.15
1835	3	343	57	+2.31	0.13	+2.18
1836	4	468	122	+1.29	1.10	+0.19
1837	4	551	138	+1.56	2.09	−0.53
1838	4	476	103	+1.96	2.69	−0.73
1839	4	468	86	+1.53	3.03	−1.50
1840	6	705	63	+0.53	3.10	−2.57
1841	5	490	37	+1.73	2.64	−0.93
1842	5	639	24	+1.62	2.13	−0.51
1843	5	580	11	+1.68	1.45	−0.23
1844	6	517	15	+1.58	0.82	+0.76
1845	4	328	40	+0.88	0.54	+0.34
1846	5	538	62	+1.11	0.84	+0.27
1847	5	453	98	+1.23	1.37	−0.14
1848	5	313	124	+0.55	2.29	−1.74
1849	5	339	96	+1.63	2.79	−1.14
1850	5	334	67	+1.89	2.89	−1.00
1851	4	325	64	+2.58	2.94	−0.36
1852	3	356	54	+1.35	2.86	−1.51
1853	3	279	39	+1.66	2.52	−0.86
1854	4	391	21	+2.39	1.91	+0.48
1855	3	312	7	+2.81	1.49	+1.32

Charting the second series (1833–1856), it is evident that one effect of the correction is to raise the effective solar constant to equal sunspot activity 60 or 70. Proceeding with the value of p obtained before $+0''.014$, we have calculated the sixth column. The seventh column, holding the residuals presents, however, in this case, a regular variation, whose maximum occurs in the neighborhood of sunspot minimum, and whose minimum occurs near sunspot maximum. The agreement is so close as to allow the suggestion that we would have obtained a similar result had we applied the same analysis to a straight line. The objection fails, however, when we consider that it would utterly fail to account for what is the most marked variation in the observed curve; which variation falls directly into the scheme, and may be thereby accounted for on satisfactory grounds. Again, the curves are not reciprocal.

We have noted the third series in the same way, save that the mean value of the spot activity is given by observation at 46. The result is identical with that of the second table. There is, however, this difference, that when the tendency of the second period was towards a positive correction the tendency of the third period is towards a negative correction, in accordance with the "residual" effect.

Apparent Correction in Longitude to LeVerrier's Tables.

Year	No. observatories	Wolf's sunspot number	Corr. to tabular longitude	Calculated sunspot effect	Residual —C′
			″	″	″
1856	4	4	+0.18	C′—1.63	+1.81
1857	5	23	+0.03	—2.23	+2.20
1858	4	55	+0.35	—1.83	+2.18
1859	3	94	+0.54	—1.60	+2.14
1860	4	96	—0.17	—0.90	+0.73
1861	4	77	—0.29	—0.47	+0.17
1862	5	59	—0.41	—0.28	—0.13
1863	4	44	—0.55	—0.31	—0.24
1864	5	47	—0.30	—0.30	0.00
1865	5	31	—0.14	—0.51	+0.37
1866	5	16	+0.63	—0.93	+1.56
1867	5	7	+0.71	—1.47	+2.18
1868	5	37	+0.45	—1.60	+2.05
1869	5	74	+0.21	—1.21	+1.42
1870	4	139	+0.19	+0.10	+0.09
1871	4	111	+0.40	+1.01	—0.61
1872	4	102	—0.22	+1.79	—2.01
1873	4	66	—0.38	+2.07	—2.45
1874	4	45	—0.23	+2.06	—2.29
1875	4	17	—0.24	+1.55	—1.79
1876	4	11	—0.88	+1.06	—1.94
1877	3	12	—0.92	+0.58	—1.50
1878	3	3	—0.97	—0.02	—0.95
1879	3	6	—0.16	—0.58	+0.42
1880	4	32	—0.44	—0.78	+0.34
1881	4	54	—0.42	—0.67	+0.25
1882	4	60	—0.07	—0.47	+0.40
1883	4	64	—0.60	—0.22	—0.38
1884	3	63	[—0.77]	+0.02	[—0.79]
1885	2	52	[—0.82]	+0.22	[—1.04]
1886	1	25	[—0.96]	—0.08	[—0.88]

$C = C' - 1''.69$

To determine the cause of this residual effect we have to satisfy the following conditions.

From the period 1800–1833 it was effective, if at all, only at the end of the period.

From that time to 1886 it has increased in efficiency so as nearly to obliterate the sunspot effect.

It must be capable both of rapidly increasing, and of rapidly decreasing the terrestrial motion to the extent of 4″.

It must have a close connection with the sunspot period.

The first, second and fourth of these conditions are met by the zodiacal light. Our earliest accounts of its appearance during the period here considered are in the neighborhood of 1830. The observations of Heis and Weber show that its elongation has constantly increased during their series. It is subject to a variation in the sunspot period of such a nature that its apparent elongation is greater at sunspot minimum than at sunspot maximum.

The variation of the mean motion of a body moving through a medium in motion may be written

$$\frac{\delta\mu}{\delta E} = \frac{3a^2\mu}{k^2}\left(T\sqrt{1-\varepsilon^2\cos^2 E} - R\,\varepsilon\sin E - V\cos\varphi\right)$$

in which T represents the resistance in the direction of the motion, R a disturbing force contrary to gravity, and V a disturbing force perpendicular to R, and opposed to the direction of motion. The other letters have their customary signification. The general requirement is, therefore, that the zodiacal light should be in motion, generally outwards from the sun. As regards the existence of such motion there is abundant evidence. As regards the sufficiency of this motion to produce the numerical result, we are in the dilemma, that on the one hand the residual result may not be entirely pure, and on the other that our criterion as regards the answers to our problem, should we calculate the forces, T, R, V, is simply reduced to what seems reasonable. We beg to wait till we shall obtain further data on that subject from a study of lunar and interior planetary residuals.

We have previously shown (this *Journal*, no. 181) that the disturbances of Encke's comet could be considered as acting in the sunspot period, and were generally speaking of the nature of the terrestrial disturbance in the period 1856–1886. Under the present result we must consider the disturbance caused both by the electrical condition of the two bodies, and also by motions in the medium. Previously it had been shown that the maximum brilliancy of the comet corresponded to the maximum of sunspot action, and the minimum to the minimum. Later it has been shown that the masses of *Mercury* calculated by means of the comet likewise showed a variation in the sunspot period.

A similar effect has been shown to exist in the motion of *Mercury*. It would seem, therefore, to be common to the bodies between the sun and the earth. But for the present our result is that the discrepancies between solar tables and solar observations may be referred to the disturbance caused in the motion of the earth by the action of sunspots and of the zodiacal light.

We have also examined the corrections to the tabular ecliptic north polar distance, and while there appears to be a variation in a period from sixteen to eighteen years, and possibly a slight variation in an eleven-year period, there does not appear to be an evident connection with the forces disclosed in this paper. We present them later.

OBSERVATIONS OF 3407 *S ANTLIAE*.

By H. M. Paul.

[Communicated by the Superintendent of the U.S. Naval Observatory.]

In this *Journal* [9 : 180] I announced the discovery of the variability of this star, and in 9 : 183, 186, 187, 189, 190, and 10 : 11, 12, 94, 95, Messrs. Chandler, Sawyer and Yendell have published the results of their observations and preliminary discussions of this remarkably short-period variable.

The following minima which I have observed thus far the present season will give an idea of how Mr. CHANDLER's ephemeris [10 : 94] is running, and will also, I hope, draw attention to some apparent anomalies in the behavior of the star which deserves the careful attention of observers.

In the small table below, the third column indicates the phase observed, "—" denoting that the time of *m* was derived entirely from comparisons on its preceding side, "+" from those on its following side, and "∓" from comparisons extending through the *m* and embracing more or less of both sides of the curve. In all cases the time of *m* was derived by plotting the observations, and fitting over them as closely as possible a tracing of the mean light-curve resulting from my observations of the three previous winters. The next two columns describe briefly the phase observed, and indicate the weight on a scale of 1, 2, 3. The column ΔT_m gives the resulting corrections to CHANDLER's ephemeris [10 : 94] with their mean by weights [$-16^m.1 \pm 3^m.6$] below, the column v giving the residuals from which the personal equation is derived.

Gr. M.T.	E	Ph.	Remarks	Wt.	ΔT_m	v
					m	m
1890 Nov. 21.0	2935	—	Regular fall, *m* not reached	2	+ 1.0	+17.1
22.9	2911	∓	Bright and irregular *m*	1	—15.8	+ 0.3
Dec. 13.0	3003	—	Bright *M*, *m* not reached	1	—25.2	— 9.1
14.0	3006	∓	Faint and irregular *m*	1	—43.6	—27.5
14.9	3009	∓	Faint *m*, rather irregular	2	—31.8	—15.7
15.9	3012	—	Obs'ns cut off early on negative side	1	—18.8	— 2.7
18.8	3021	+	Pretty regular rise	2	+ 0.9	+17.0
19.8	3024	∓	Bright *m*, rise irregular	3	—15.2	+ 0.9
				Mean by weights.	—16.1	± 3.6

These same residuals [col. v] give $\pm 9^m.0$ as the personal equation of the observed time of a single *m* of wt. 2. Each of these *m* depends upon from 4 to 27 careful comparisons [13 on the average] made at intervals of from 5^m to 10^m when near *m*, or even (in some cases when the light changes appeared rapidly irregular) as frequently as 3^m or 4^m, as rapidly as they could be carefully made and recorded. These minima thus represent, on the average, more complete and careful determinations than those from my observations of the preceding winters, and the magnitude of the resulting residuals appears to confirm the probable reality of the residuals of the best observed *m* of previous seasons, both of my own and of those of CHANDLER, SAWYER and YENDELL, of which I will now speak.

As I wished to combine all the observations to date in a solution for the most probable epoch and period, all these gentlemen kindly complied with my request and sent me a copy of all their original comparisons, those of Mr. SAWYER extending 18 days later than the last of those published in 9 : 189. All these I reduced with my own light-scale [given below, near end of this paper], plotted each observer's results separately (using the assumed elements, $T_m = 1888^y\ 104^d.520 + 0^d.32417\,E$), and then drew the smoothest curve possible through those of SAWYER, YENDELL and myself. As CHANDLER's observations were not numerous enough to determine a curve, I drew a mean curve between SAWYER's and my own [making them coincide as nearly as possible at the steepest parts], then made this fit as closely as possible among CHANDLER's observations, and used this for his light-curve. YENDELL's observations appear to give the star a considerably less range than those of the other three, his *M* being generally fainter, and *m* considerably brighter, and hence his light-curve is considerably flatter in shape, and the individual comparisons seem subject to a greater accidental error.

I cannot regard any of these curves as at all final, although my own depends upon about 575 observations, extending over three winters; but since, on account of the irregularities of individual *m*, any mean light-curve is likely to be of rather limited use in reducing observations, I prefer not to publish any till a more complete study of these irregularities can be made. The following table will give a general idea of the accordance of the different curves. The "General Range" includes all except one or two extreme observations in each case, which may be regarded as exceptional. CHANDLER's observations are not sufficient in number to get an idea of the general range at *M* and *m*.

Observer	No. of obs'ns	Mean Curve		General Range	
		M	*m*	*M*	*m*
Chandler	24	12.2*	6.2*	13.4† . .	. . 5.9†
Paul	575	12.5	5.7	13.8 to 11.0	7.2 to 5.2
Sawyer	103	12.0	6.8	12.2 " 11.3	7.7 " 6.6
Yendell	130	11.5	8.0	12.8 " 10.1	9.7 " 7.1

* Mean of P. and S. † Extreme observations.

I am disposed to think that my observations during the first two winters perhaps exaggerated the faintness at minimum on some nights, and that the later observations may give a slightly higher curve at *m*.

Selecting out of the great mass of the observations those which fell on sufficiently steep parts of the curves for determining corrections to times of *m* [generally lying between 11.0 and 7.0 for C., P. and S., and between 10.2 and 8.2 for Y], I have deduced more or less accurate corrections to the assumed times of the minima summarized in the following table, where the first line gives the number of *m* available, and the second line the average number of comparisons upon which each depends.

Observer	Chandler	Sawyer	Yendell	Paul 1887–8	Paul 1888–9	Paul 1889–0
Number of *m* determined	6	20	13	5	36	21
Average number of observations per *m*	2.0	2.4	2.5	3.8	3.8	4.3

I did not finish the solution for most probable elements, being diverted to the study of the residuals on account of their magnitude and irregularity, of which those in column *v* of the first table of this paper are only a moderate sample. Chandler's elements [9 : 186, 187, 190] will be amply accurate for prediction for some time to come, and as his period is very convenient for the construction of an ephemeris [see 10 : 94, 95] there is no occasion for new elements at present. I may say that this period will be very little changed, but the epoch probably needs a correction of something like —20^m, as the weeding out of a great part of my poorer observations of the first season [see 9 : 180] makes the 0-epoch earlier, and it is proper here to state that the correction of $+5^m.0$ on 9 : 190 for "Red. to ⊙" was not needed, as all my observations had been reduced to heliocentric time before discussion. This I inadvertently omitted to state on 9 : 182.

Deeming the study of the irregularities to be the next point for investigation as regards *S Antliae*, it will perhaps be interesting, and possibly instructive, to collect in the next table the corrections to Chandler's elements for all the *m* which have happened to be observed by two or more observers. The first column gives the number of the *m*. Under each of the four observers the column "Obs." gives the number of comparisons described above as falling on a sufficiently steep part of the curve to give a correction to *m*, those on the preceding side under "—" and those on the following under "+" respectively. The weights *p* are $\frac{1}{4}$ the sum of those assigned to the individual observations [before the reduction began] for C., P. and S., and $\frac{1}{8}$ this sum for Y. These are the weights used in the least-square discussion not yet completed. The quantities ΔT_m are the observed corrections to Chandler's elements.

E	Chandler			Paul			Sawyer			Yendell		
	Obs. — +	*p*	$T\Delta_m$	Obs. — +	*p*	ΔT_m	Obs. — +	*p*	ΔT_m	Obs. — +	*p*	ΔT_m
			m			m			m			m
1157	1 –	0.50	—51.8	– 3	0.56	—17.3	. .	. .	. .	. .	. .	. .
2092	. .	. .	. .	. .	. .	. .	2 –	0.88	— 3.1	1 –	0.19	—39.4
2095	. .	. .	. .	. .	. .	. .	1 –	0.50	—27.7	1 –	0.19	—22.0
2141	. .	. .	. .	3 –	0.88	—15.9	. .	.	. .	1 1	0.31	—13.1
2144	. .	. .	. .	. .	. .	. .	– 2	0.62	+14.5	1 2	0.56	—15.6
2166	. .	. .	. .	1 4	2.75	—13.5	1 –	0.50	—16.2	. .	. .	. .
2169	. .	. .	. .	. .	. .	. .	1 –	0.25	—33.9	2 –	0.50	—31.6
2181	. .	. .	. .	. .	. .	. .	1 2	1.00	+ 5.6	– 2	0.44	+15.9
2190	. .	. .	. .	. .	. .	. .	– 3	1.25	+ 4.3	– 1	0.19	+11.1
2200	.	. .	. .	. .	. .	. .	1 –	0.38	+14.0	1 –	0.12	—63.2
2209	3 –	1.12	+28.2	. .	. .	. .	4 –	1.12	+40.9	. .	. .	. .
2227	– 1	0.50	— 1.9	. .	. .	. .	– 1	0.25	+27.3	. .	. .	. .
2246	. .	. .	. .	3 3	1.38	—19.3	2 3	2.00	—32.5	4 3	1.56	—33.4
2249	1 –	0.50	—16.4	1 3	0.69	—20.6	. .	. .	. .	3 1	0.81	— 8.3
2258	. .	. .	. .	. .	. .	. .	– 2	1.00	—10.3	– 4	0.62	—32.2
2274	. .	. .	. .	4 –	1.06	—46.2	. .	. .	. .	1 –	0.12	—37.9
2289	. .	. .	. .	. .	. .	. .	1 3	1.38	—20.1	2 2	0.88	+ 1.2

I do not think that most of the above corrections, which depend upon only one or two comparisons on one side of *m*, have much real meaning; but, in the case of such *m* as 2209 and 2246, the approximate agreement between different observers, when the weights are considered, indicates a probably real correction to the time of *m*. The others will serve to call attention to the necessity for very frequent comparisons, extending them to both sides of *m* whenever possible, and using extreme care on account of the small total range of variability. It is only fair to note that Mr. Chandler [9 : 190] specially disclaimed any accuracy in his determination of *m* 1157.

Besides the irregularities in the times of *m*, my own observations indicate considerable range in their duration [so that *m* determined from only one side of the curve would be liable to some error on that account], also considerable range in the average brightness near *m* [the brighter *m* probably the longer and flatter, and the fainter the shorter and steeper, curves], and with all of them more or less rapid and irregular fluctuations in brightness, sometimes amounting to 2 or 3 steps. I would like the help of careful observers in attempting to determine how much of this is real, and how much may perhaps be due to personal equation or predisposition of the observer. Certainly, if I have any such predisposition, it would be in favor of seeing the variable go down and up on a smooth regular curve, but it will not apparently do so.

A word as to instruments. All my observations, except a part of the first season's, have been made with an excellent field-glass magnifying about 4 times. This is rather deficient in optical power for comparisons near *m* [both in gathering light and in separating *S* from its nearest bright neighbor, *w* in the scale below], and it is probable that the accuracy of the comparisons is somewhat diminished near *m* on this account. Nevertheless, I have thought it better to keep up the symmetry of the observations with the same instrument for the present, until something much more satisfactory can be obtained.

With this kind of optical assistance I find it decidedly convenient, and I think conducive to accuracy, to have a plenty of comparison-stars with as small light-intervals as possible, even if some of them are rather distant, and to any observers using field-glasses of moderate power I would strongly recommend this plan. Hence I republish here a part of my light-scale covering the range of *S*, with the added values of last winter's determinations, and including the stars used by the other observers, one or two other faint ones in the vicinity, and the position of *S Antliae* itself.

Star	1875.0		Light			Letter	*M*
	α	δ	1887–8	1888–9	1889–0		
	h m s	° ′					
66 *U.A. Pyxidis*	9 21 18	—28 14.8	15.7	15.7	15.6	*v**	6.43
52 *U.A. Pyxidis*	3 17	26 15.8	14.6	14.6	14.7	*a*	6.54
25 *U.A. Antliae*	39 52	29 37.7	12.9	12.6	12.4	*e*	6.74
58 *U.A. Pyxidis*	8 1	29 9.0	9.8	10.2	10.3	*q*	6.99
7 *U.A. Antliae*	25 12	28 13.0	8.9	8.8	8.7	*w**	7.12
21 *U.A. Antliae*	36 24	29 44.1	8.6	9.1	8.8	*f*	7.12
57 *U.A. Pyxidis*	7 0	28 26.1	8.2	8.2	8.5	*p*	7.17
Lacaille 3829	20 47	29 29.7	6.2	6.0	6.0	*x*	7.39
Lacaille 3942	32 1	29 14.4	4.5	4.4	4.6	*k*	7.55
Lacaille 3751	10 44	28 22.0	3.5	3.2	3.3	*m*	7.67
5 *U.A. Antliae*	24 29	27 41.7	[3.5]	[0.4]	[2.7]	*n**	[7.78]
Oe. Arg. S. 9784	9 24 37	—28 2.8	2.2	1.8	1.7	*o*	7.81
S Antliae	9 26 50	—28 4.7	. .	. .	. .	*S*	var.

The magnitudes in the last column are the mean of the results of the three seasons, given in the preceding columns, magnitude and light being connected by the relation, $M = 8.00 - 0.1$ st. For the method of determining this light-scale, as well as for the explanation of the rather confusing assignment of letters, see 9 : 181; where, however, in the first line of the second column below the table, the reading should be "I have not thought it necessary," etc. The above values of *L* for 1889–0 were determined precisely as there described for 1887–8 and 1888–9.

To my eye, with the field-glass mentioned, the *M* of *S Antliae* range round the star *e*, sometimes brighter, sometimes fainter, more generally the former; while the *m* generally go a little below *x*, occasionally nearly as faint as *k*, and sometimes getting scarcely down to *x*. The three stars marked with an * are the ones used by Chandler, Sawyer and Yendell [see 9 : 189]. With field-glasses of high power, or with small telescopes, they are very convenient on account of proximity to *S*. I have used *w* but little on account of its reddish color. It is exceedingly convenient, however, for comparison, being the nearest neighbor of *S*, and midway in its range of brightness, where it is changing rapidly. If care is taken in slight twilight, moonlight or haze to check it by *f* or *p*, no very appreciable error will probably enter the work.

I can hardly think this is the case, however, with the use of *n*, especially when it is depended upon entirely for the lower range of *S*. On 9 : 181 *f* noted its probable variability, and my later observations tend to confirm this. Though down to about the limit of accurate comparison with my glasses, I can hardly think its apparent fluctuations wholly imaginary. My estimates of last season [18 observations on 15 nights, and covering the period of Chandler's, Sawyer's and Yendell's observations] ranged from 0 to 4 in the above scale. I would strongly recommend the use of *x* and *k* for comparisons of *S* near minimum; but, if these are too far off, then *o*, though too faint, would, perhaps, be more reliable than *n*.

SUN-SPOT OBSERVATIONS,

MADE AT THE HAVERFORD COLLEGE OBSERVATORY WITH THE 8-INCH EQUATORIAL,

BY F. P. LEAVENWORTH.

1890	Time	Grs.	Sps.	Fac. Grs.	Def. and Size
July 1	10	0	0	0	fair ; 2 large
4	10	2	11	1	good ; 4 "
5	5	1	22	3	good
6	5	1	25	3	fair
7	12	1	33	2	fine : 2 large
8	11	3	32	0	good : 3 "
9	11	2	48	0	–
10	11	2	28	0	fair
11	3	2	10	1	fair
12	11	2	5	0	poor
14	12	1	4	2	fair
15	11	1	2	2	good : small
16	10	0	0	1	poor
17	11	1	1	0	fair ; small
18	5	0	0	1	good
19	5	0	0	1	good
20	5	0	0	0	good
21	10	0	0	0	poor
22	10	1	3	1	bad
23	12	2	9	2	fair ; 1 large
26	5	1	20	0	good ; 1 "
27	5	1	12	1	good
30	11	4	13	1	good ; 1 "
31	10	6	11	2	good ; 1 "
Aug. 1	12	3	22	2	poor ; 1 "
2	5	3	4	2	1 large
3	5	1	2	0	bad
4	5	1	5	1	fine : 1 "
5	5	2	9	1	poor
6	5	2	14	1	good
7	4	2	3	1	
9	5	0	0	1	good
11	9	1	2	1	fair
13	5	0	0	1	fair
14	3	1	2	1	fair ; small
15	4	0	0	0	good
16	11	1	3	0	poor : small
17	11	0	0	0	good
18	3	0	0	0	poor
19	12	0	0	1	good
20	6	0	0	0	fair
22	5	2	3	1	good : small
24	4	3	8	1	fair
25	3	2	21	1	gd : 1 large
26	11	1	24	1	pr ; sev'l lar
Aug 27	3	2	78	2	gd ; 1 v lar
28	3	2	96	1	gd : 2 "
29	3	1	60	0	fair ; 2 "
30	3	1	10	1	gd ; 2 "
31	3	2	88	0	fair
Sept. 1	3	2	65	1	poor : 3 lar
2	10	2	59	1	fair : 2 "
3	9	2	54	2	fair ; 2 "
4	10	3	52	1	gd : 1 v lar
6	5	5	37	5	good : 1 "
7	4	5	44	8	fair : 1 "
8	10	4	20	4	poor ; 1 "
9	3	4	34	2	fair
10	11	2	31	0	fair ; small
12	11	2	25	0	poor : "
13	10	1	6	1	fair ; "
15	3	2	14	5	poor ; 1 lar
17	12	1	17	1	fair : 2 "
18	11	2	28	1	fair : 2 "
19	12	3	35	3	fine ; small
20	10	1	7	2	fair
21	3	2	4	1	fair
23	11	3	24	5	fine ; v sm
24	10	1	13	3	fair
25	12	1	30	4	good
28	4	1	37	2	fair ; small
29	10	1	17	2	poor ; "
30	10	1	23	0	poor
Oct. 1	9	1	28	0	fair ; small
3	11	0	0	2	fair
4	10	1	2	5	good
5	3	2	14	2	good : small
8	9	1	1	2	good : "
9	9	0	0	1	bad
10	11	1	1	2	fair
11	10	2	8	2	fair
14	1	1	2	1	poor
15	10	0	0	2	poor
17	9	0	0	2	fair
18	10	0	0	1	good
25	10	1	50	. .	poor ; 1 lar
26	9	1	40	1	poor ; 1 "
27	2	1	24	0	fair ; 1 "
28	9	1	8	2	poor ; 1 "
Oct. 29	2	1	16	3	1 large
30	10	1	2	3	fair ; 1 "
31	10	1	4	3	fair
Nov 1	11	2	2	3	1 large
3	9	0	0	0	fair
4	10	1	1	1	fair : veiled
5	10	9	0	0	good
6	11	0	0	0	fair
7	12	1	6	1	good ; 1 lar
8	11	1	10	1	fair ; 1 "
10	10	1	5	1	poor
13	2	3	8	0	good
14	10	1	2	1	good : small
18	10	0	0	3	fair
19	10	0	0	2	fair
20	12	0	0	2	fair
21	10	1	1	3	fair
22	10	1	1	2	poor : 1 lar
23	10	1	19	1	fair : 1 "
24	10	1	65	1	fine ; 1 "
25	10	1	47	0	good ; 3 "
26	12	1	53	2	fair ; 4 "
27	12	1	35	2	poor
28	11	1	30	2	poor
29	10	1	65	0	good : 2 lar
30	3	2	29	1	good : 1 "
Dec. 1	10	3	13	2	fair : 2 lar
2	11	2	8	1	good : 1 "
4	11	0	0	2	fair
9	2	1	4	1	good
10	10	1	3	1	good : small
11	11	1	2	1	good ; "
12	11	0	0	0	poor
13	11	2	15	2	fair
14	12	2	32	1	fair
15	9	2	32	2	fair
18	3	2	21	0	bad
19	10	3	24	2	poor ; 1 lar
20	1	3	31	2	good
22	10	0	0	1	fair
23	10	1	2	2	poor
24	10	1	6	2	poor : sm

ELEMENTS AND EPHEMERIS OF COMET *f* 1890.

BY REV. G. M. SEARLE.

I have computed elements of SPITALER's comet from the discovery observation, and those made by BARNARD on Dec. 7 and Jan. 7, as follows:

$$T = \text{Oct. } 22.6141 \text{ G.M.T.}$$
$$\Omega = 45^\circ\ 32'\ 50''$$
$$\omega = 11\quad 8\quad 32$$
$$i = 13\quad 7\quad 33$$
$$\log q = 0.261911$$
$$\varphi = 29^\circ\ 17'\ 31''$$
$$\log a = 0.553739$$
$$\log \mu = 2.719398$$
$$\text{Period} = 2473 \text{ days or } 6^y.77$$

The residuals (O—C) for place are $\Delta\lambda = +14''$, $\Delta\beta = +7''$; this comes merely from the approximation being incomplete, as it did not seem worth while for the present to attempt an accurate result.

The coordinate equations for 1891.0 are:

$$x = [9.994216]\, r \sin (v + 115^\circ 56' 11'')$$
$$y = [9.927280]\, r \sin (v + 61\ 53\ 36)$$
$$z = [9.716291]\, r \sin (v + 11\ 47\ 2)$$

These give the following ephemeris, for Greenwich midnight:

Date	α	δ	log Δ	Br.
1891 Jan. 21	4h 54m 24s	+40° 20′.2	0.0761	0.51
25	56 32	40 15.2	.0913	.47
29	59 20	40 9.0	.1067	.43
Feb. 2	5 2 40	40 1.9	.1222	.33
6	6 36	39 53.9	.1378	.36
10	5 11 0	+39 45.2	0.1532	0.33

NEW ASTRONOMICAL WORKS.

Die Spectral-Analyse der Gestirne, von Dr. J. Scheiner, *Astronom am königlichen astrophysikalischen Observatorium zu Potsdam.* Leipzig, *Verlag von* Wilhelm Engelmann, 1890.

In this elaborate and important work the great need of a trustworthy text-book on the analysis of the spectra of the heavenly bodies seems to have been supplied in a most satisfactory manner. The results of the most recent observations are not merely recounted, but carefully criticized; and the student of astrophysics will find a repertory of what has thus far been attained in our knowledge of the spectra of stars and nebulas, as well as of those of the bodies of our solar system.

In the first Part are described the various forms of apparatus devised for the study of spectra, and especially those employed for examining the light of celestial objects. In the second, the theories of spectral analysis are historically and mathematically discussed. The third gives the results thus far obtained from study of the celestial spectra. Finally, the fourth contains: (1) extensive tables of wave-lengths for the visible solar spectrum, founded on those already published by the Potsdam observatory; (2) Thalen's tables of wave-lengths for the lines of the iron-spectrum; and (3) a catalogue of the stars belonging to the class III *a* and III *b*, as derived from Duner's catalogue and Vogel's spectroscopic *Durchmusterung.* In an appendix is a full bibliography of the subject.

The volume, which is abundantly illustrated by figures in the text, contains also photographic reproductions of the spectra of eight fixed stars, exemplifying the different types of stellar spectra. Prof. Vogel introduces it by a preface.

Katalog der Argelander*'schen Zonen vom 15, bés 31, Grade Südlicher Declination, in mittleren Positionen für* 1850.0. *Herausgegeben von* Dr. Edward Weiss. Wien, 1890.

This work, which forms a supplementary volume to the Annals of the new observatory of the Vienna University, takes the place of the well-known catalogue constructed by Oeltzen from Argelander's southern zones and reduction-tables. The latter, originally published by instalments in the *Sitzungsberichte* of the Vienna Academy of Sciences, and long since out of print, contains a large number of errors, comprising those of observation, of printing, of the tables and of reduction. It has rendered inestimable service to astronomers; yet only in comparatively few cases, until recently, could its positions be tested by comparison with independent observations. Argelander himself had detected a considerable number of mistakes in the original records of observation, and other lists of errors have, from time to time, been collected by other observers; but Schönfeld's Southern *Durchmusterung* and the Cordoba catalogues now afford a means for controlling the greater part of the positions.

Professor Weiss has now compared all the stars, north of 23°, with the former, and all south of that parallel with the latter, of these independent authorities. About a thousand of Argelander's stars, in the southern portion, were not found in the Cordoba zones, and for about two hundred more a reference to the sky was found desirable. These 1200 stars have been examined at Vienna with the equatorial, and some few changes, which correspond to plausible conjectures of error in the observations, have been made in the deduced positions, but all such cases are carefully specified in the notes, together with the reasons for the change. Only 11 stars remain, for which no simple and probable conjecture brings Argelander's position into accord with the sky.

The resultant catalogue, now published, contains the places of 18276 stars. For these, 23250 positions are given in Oeltzen's reduction, — in which each observation is separately numbered, — so that it is not always easy to distinguish between two observations of a single star, and observations of two different stars, in close proximity.

The magnitudes in Oeltzen's catalogue have also been subjected to careful comparison; this being facilitated by an index of the zones existing at the Bonn observatory. The number of corrections thus found requisite was very small, except in two places (Oe. 2039–2083 and 4771–4781), where, in the column of magnitudes, the values appear to have been shifted from their proper positions by some error in the printing-office, after the last corrections of the proof-sheets.

The numbers of stars observed by Argelander, and those of his several observations, are given for each hour of right-ascension in a table in the preface; the proper motions of those stars, for which the comparison with later catalogues shows them to be considerable, are collected in a special table of the appendix; as also are 18 variable stars, which occur here, — the variability of two of these having been recognized during the process of revision.

The whole volume is stereotyped, its mechanical execution is elegant, and its arrangement unusually convenient. By the side of the positions for 1850.0 are given the values of the total precession which refer them to the mean equinox of 1875.0; and, in addition to Oeltzen's numeration, the original zone and number are shown for every observation.

It may not be too much to hope that Prof. Weiss's success may incite some adequately endowed observatory to a similar reduction and revision of Bessel's zones. The new catalogues of the *Astronomische Gesellschaft* will afford admirable facilities for such an undertaking.

CORRIGENDA.

No 229, p. 103, M.T., Nov. 18, *for* $11^{h}\ 26^{m}\ 33^{s}.9$ *put* $10^{h}\ 56^{m}\ 38^{s}.8$. The declinations on same date should possibly be increased by $1^{\text{rev.}} = 15''.3$.

CONTENTS.

A Study of the Discrepancies between Tabular and Observed Solar Positions 1800–1886, by Mr. Orray Taft Sherman.
Observations of *S* Antliae, by Prof. H. M. Paul.
Sun-Spot Observations, by Prof. F. P. Leavenworth.
Elements and Ephemeris of Comet *f* 1890, by Rev. G. M. Searle.
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ON THE MEAN AND SECULAR MOTION OF THE MOON'S PERIGEE.

BY JOHN N. STOCKWELL.

1. In number 231 of this *Journal* I announced that I should give the result of my examination as to the effect of the change in the form of the differential equation of the moon's perigee, which was suggested by Prof. HILL in No. 226 of this *Journal*, upon the secular motion of the perigee. This I have now done, and the labor of the examination not having been so great as was anticipated, I am enabled to publish my results sooner than I had expected.

2. In the first place, I retract, unconditionally, the admission there made as to the correctness of the first point of Prof. HILL's criticism. My equation (1) which he criticises, is entirely rigorous. The periodic perturbations in the value of e of which he speaks, are self-eliminating, since e enters both members of the equation in the same way; and any periodic perturbations in the value of ω are retained, and enter into the final result. It is true that the equation is not in the form given by most astronomers, although it has the same form that was given it by LAPLACE in the *Mécanique Céleste*.

3. The differential equation of the perigee is derived from the following equation:

$$\tan\omega = \frac{f'}{f} \tag{1}$$

in which the values of f and f' are given by the equations

$$f = r^3\frac{dv^2}{dt^2}\cos v + r^2\frac{dr}{dt}\frac{dv}{dt}\sin v - \mu\cos v \tag{2}$$

$$f' = r^3\frac{dv^2}{dt^2}\sin v - r^2\frac{dr}{dt}\frac{dv}{dt}\cos v - \mu\sin v \tag{3}$$

The quantities f and f' are therefore functions of the coordinates r, v, and of their differentials divided by dt; and the differential equation of ω must contain the four quantities

$$r,\quad v,\quad \frac{dr}{dt} \text{ and } \frac{dv}{dt}.$$

When the proper operations are performed, we shall obtain the following equation:

$$\mu e\frac{d\omega}{dt} = r^2\cos(v-\omega)\frac{dv}{dt}\cdot\left(\frac{dR}{dr}\right) + \left\{\cos(v-\omega)\frac{dr}{dt} - 2r\sin(v-\omega)\frac{dv}{dt}\right\}\left(\frac{dR}{dv}\right) \tag{4}$$

which is the equation criticised by Prof. HILL. He however transforms it into the following equation: (5)

$$\frac{d\omega}{dt} = \frac{r^2\frac{dv}{dt}\left\{r^3\frac{dv^2}{dt^2}-\mu\right\}\cdot\left(\frac{dR}{dr}\right) - \frac{dr}{dt}\left\{r^3\frac{dv^2}{dt^2}+\mu\right\}\cdot\left(\frac{dR}{dv}\right)}{\left\{r^3\frac{dv^2}{dt^2}-\mu\right\}^2 + r^4\frac{dr^2}{dt^2}\frac{dv^2}{dt^2}}$$

by the substitution of the quantities

$$\mu e\cos(v-\omega) = r^3\frac{dv^2}{dt^2}-\mu,\quad \mu e\sin(v-\omega) = r^2\frac{dr}{dt}\frac{dv}{dt} \tag{6}$$

In regard to equation (5) Prof. HILL remarks that the second "member is expressed purely as a function of the four quantities

$$r,\ v,\ \frac{dr}{dt} \text{ and } \frac{dv}{dt}."$$

But in this he is certainly mistaken; for, in eliminating ω, he has also eliminated v, the moon's longitude, which is an essential element of the problem; and the second member of equation (5) does not contain v explicitly, but merely its differential dv. Equation (5) is therefore essentially defective, inasmuch as it does not contain all the elements which are included in the values of f and f'. It gives, however, the correct value of $\frac{d\omega}{dt}$ in so far as it depends on the first power of the disturbing force; but the derivative functions which determine the squares and higher powers are altogether erroneous. I have, however, employed it to determine the increment of $\frac{d\omega}{dt}$ arising from the square of the disturbing force; and, unless I have made some grievous blunder in the calculation, we shall find the daily increment of the longitude of the perigee to be $-17'\ 33''$; and the secular motion of the perigee arising from the same cause would be $-380''.i^2$, in which i denotes centuries. Therefore, according to Prof. HILL's improved formula the lunar perigee ought to have a daily retrograde motion of about 15′ instead of a direct motion of about 7′, according to observation. It is therefore easy to see that equation (5) is totally unfit for determining the motion of the lunar perigee.

4. In my former communication I discussed Prof. ADAMS's solution of the problem of the moon's secular acceleration; and incidentally remarked that Prof. HILL obtained the same result by means of a totally different and incompatible law of the variation of the solar eccentricity. It is indeed a singular feature of all the solutions of this problem which have appeared during the past thirty years, in which the solar eccentricity has been treated as variable in the solution, that the results of the different solutions should all be the same, notwithstanding the difference in the assumed laws of such variation. For example, Prof. ADAMS assumes that the differential of the eccentricity divided by the differential of the time is a constant quantity; while Prof. HILL assumes that the differential of the square of the eccentricity divided by the differential of the time is also a constant quantity; and yet they both obtain the same result for the effect on the moon's motion. Now, both of these hypotheses cannot possibly be true at the same time, unless the eccentricity is itself constant, in which case its differential divided by the differential of the time would be equal to nothing. Each solution ought then to reduce to what it would have been, in case the eccentricity had been regarded as constant in the solution. But they do not; and I have thought that the explanation of this feature of the different solutions might, perhaps, be interesting to astronomers. The whole explanation of these remarkable results may be traced to the methods of obtaining the integrals of the differential functions which arise in the development of the equations. A single example, which I take from Prof. HILL's investigation of the secular acceleration of the moon, which is given on page 107 of *The Analyst* for July, 1878, will sufficiently illustrate my meaning.

In the equation there given, if we put for abridgement

$$\beta = -\tfrac{15}{2}\frac{n'^4}{n^3}\frac{d.A}{d.e'^2},$$ it will become

$$\frac{dn}{dt} = \beta\,\frac{d.e'}{dt} \qquad (7)$$

Now, by hypothesis $\frac{de'^2}{dt}$ is a constant quantity; the correct integral of equation (7) would therefore be

$$n = n_0 + \beta\,\frac{d.e'^2}{dt}\,.\,t \qquad (8)$$

in which n_0 is the value of n when $t = 0$. But Prof. HILL gives for the integral of the same equation

$$n = \beta e'^2, \qquad (9)$$

which is certainly a wonderful transformation, the constant and variable having both been eliminated by integration, and a new variable introduced in its stead.

I have thus shown that the solutions given by Professors ADAMS and HILL are essentially erroneous; but even if we assume them to be correct, it remains for them to show, *first*, why results arising from an assumption that is admitted to be false, or rather, of an assumption that is not claimed to be true, but only convenient, should be considered a legitimate part of a correct physical theory; and *secondly*, they ought also to show why results arising from two incompatible hypotheses should give identically the same value for the moon's secular acceleration. If my memory serves me rightly, these are points that did not enter into the discussion of the question thirty years ago, but which nevertheless ought to be considered before conclusions based on them can be regarded as well established parts of any physical theory of the moon's motion.

I conclude, therefore, that Prof. HILL's criticism does not invalidate in the least, the investigation given in Nos. 220 and 221 of this *Journal*.

Cleveland, Ohio, 1891 *Jan.* 14.

ON THE PERIOD OF 466 *U PISCIUM*,

BY HENRY M. PARKHURST.

In the first announcement by Dr. PETERS, in the *Astr. Nachr.*, of the variability of this star, its position was stated 2° too far north. Not finding the comparison-stars there, I suspected a typographical error, which I soon verified. Possibly on account of this error, the only published observations I have seen are those of Dr. PETERS himself.

The period of 352 days, in CHANDLER's tables (*A.J.* No. 179), was derived from my observations from 1884–6. The star reappeared in January, 1887, but I did not observe it at its maximum, and shortly after I suspended the direct observation of variables, in order to observe asteroids.

Soon after the publication of CHANDLER's table I analyzed my observations more carefully, and became satisfied that the period given was twice the true period, and that there was a maximum in February, 1887. Since the publication of the Zone-Catalogue, (Harv. Annals, vol. 24), I have observed photometrically my comparison-stars, and have reduced all my observations, and also those of Dr. PETERS, from 1879 to 1888, as well as an additional observation of my own in 1891, to magnitudes, upon the scale of the Harvard Photometry. There are about 34 of my own, omitting a few observations during invisibility, and 26 of Dr. PETERS; making a total of 60. Unfortunately there are very slender materials for determining any maximum, and still less a minimum, with accuracy; but with my deduced period I have compared every maximum and minimum which has occurred since the discovery by PETERS in 1879. I select those which tend to fix the period.

	M
1881 Nov. 20	11.2
27	11.3
1885 Sept. 17	11.5
21	11.2
29	11.5
Oct. 10	12.1
1886 Aug. 30	11.1
1886 Sept. 3	11.1
1887 Jan. 26	12.1
Feb. 10	11.8
25	12.1
1888 Dec. 23	11.0
1891 Jan. 9	13.2

From my observations in 1885, which were photometric, I deduced $E =$ Sept. 22, 1885. I also deduced the conclusion that the variable falls to $11^M.5$ within 6 days of its maximum. The maximum, therefore, must have occurred between Peters's two observations in 1881. Assuming Nov. 22 the period becomes 175 days, which is consistent with all prior observations, there being no prior observations above $11^M.6$. Assuming a maximum on Sept. 1, 1886, the period would then be 172 days; and it was certainly much less than 175 days. The observations of 1887, when the maximum was unexpected, do not fix the date, but only determine that the former period was double. A period of 169 days brings the maximum on Dec. 24, 1888. Dr. Peters's single observation must have been amost exactly at the maximum, being above any other recorded. Continuing the period of 172 days up to 1891, for comparison with my last observation, the variable would not reach the observed brightness before Jan. 19, still further showing a diminution of the period. On Jan. 9, it was of the same brightness as on Oct. 23, 1886, the only evening in which Dr. Peters and myself simultaneously observed it, and on that evening we exactly agreed in our estimate.

From the above data I deduce, $E =$ Sept. 22.0, 1885; and period $= 172.2\,E - 0.33\,E^2$. Mag. $11^M.0$ to $<11^M$.

From this equation, the critical dates result as follows:

Maxima,	1881 Nov. 23.1	Maxima.	1887 Feb. 17.6
	1885 Sept. 22.0		1888 Dec. 24.1
	1886 Aug. 31.1		1890 Oct. 19.9

It seems unnecessary, in view of the meagre data. to attempt greater accuracy at present.

For the light-curve, I deduce the following table, subject to an average variation of 6 days:

Mag.	Days from Max.	
11.0	+ 0	— 0
11.5	10	8
12.0	20	15
12.5	40	30
13.0	60	50
13.5	70	60
14.0	+80	—70

Probably the maximum in 1884 was only $11^M.5$. and perhaps in other years.

New York, 1891 *Jan.* 12.

Jan. 15. The new elements given in Chandler's Supplement (*A.J.*, No. 216), I had not seen when the above was written. The observations seem to me to indicate an unmistakable and rapid shortening of the period during the last ten years.

H. M. P.

OBSERVED MAXIMA AND MINIMA OF SHORT-PERIOD VARIABLES IN *SAGITTARIUS*.

BY PAUL S. YENDELL.

X Sagittarii.

This star was observed from June 10 to Sept. 8, during which time 38 observations were obtained; from these are deduced, by the single light curves, six maxima and four minima, as follows:

Maxima	w	Minima	w
1890 June 16.8	2	1890 June 20.2	1
July 7.3	4	July 10.1	2
13.3	3	17.4	3
21.4	2	Aug. 15.3	2
Aug. 4.5	2		
19.8	2		

W Sagittarii.

W Sagittarii was first observed this year on June 10. from which date to Sept. 29. 42 observations were made; from these have been deduced 14 maxima and 4 minima; all, with the exception of the maximum occurring on July 18, were obtained by the use of a provisional mean light-curve. The observed times are as follows:

Maxima	w	Minima	w
1890 June 9.98	1	1890 June 16.4	2
17.92	4	July 8.6	2
25.82	2	16.4	4
July 3.93	2	Aug. 15.3	1
11.09	5		
18.70	4		
25.11	1		
Aug. 2.82	4		
10.90	1		
17.71	2		
Sept. 2.03	4		
9.23	2		
17.55	1		
30.02	1		

Y Sagittarii.

A series of 17 observations of this star, from June 10 to Sept. 30, yields to the application of a mean light-curve, 15 maxima and 7 minima; the observed times are as follows:

Maxima	w	Maxima	w
1890 June 17.26	3	1890 Sept 8.56	2
29.23	1	18.50	3
July 5.67	4	29.90	2
11.29	3		
17.58	4	Minima	
22.88	2	July 9.18	2
Aug. 3.86	4	19.88	1
8.96	2	Aug. 7.50	2
15.86	2	13.51	2
20.81	1	18.67	1
27.69	1	30.27	2
Sept. 1.50	3	Sept. 5.41	2

V Sagittarii.

V Sagittarii as in the preceding year was the subject of a series of observations made simultaneously with those of *U*, given below; maxima indicated on June 17, July 7, and August 16, and minima on June 28 and August 28. The three maxima were of uniform magnitude, and estimated as 7^M.5; the first minimum was 8^M.0, and the second 8^M.6; when last observed, Sept. 30, the star's light was estimated at 8^M.4.

Dorchester, Mass., 1890 *Dec.* 26.

U Sagittarii.

U Sagittarii has been the object of particular attention, and was observed 47 times from June 10 to Sept. 30; from these observations have been deduced 13 maxima and 5 minima; nine of the former by the employment of a mean curve, the remaining four, with all the minima, by the single light-curve.

Maxima	w	Maxima	w
1890 June 16.6	3 *c*	1890 Aug. 9.4	4
21.7	1	16.5	4 *c*
29.7	1	30.4	4 *c*
July 6.3	4	Sept. 6.4	3
13.5	3	19.5	3
19.8	3 *c*	26.9	2
Aug. 2.4	4		

Maxima marked *c* are those found from the single curves.

Minima	w
1890 July 17.3	1
Aug. 5.4	3
14.4	3
Sept. 2.1	3
23.3	1

OBSERVATIONS OF COMET *f* 1890 (*SPITALER, Nov. 16*),

MADE WITH THE 12-INCH AND 36-INCH REFRACTORS OF THE LICK OBSERVATORY,

BY E. E. BARNARD.

1891 Mt. Hamilton M.T.		*	No. Comp.	☄ — *		☄'s apparent		log $p\Delta$	
				$\Delta\alpha$	$\Delta\delta$	α	δ	for α	for δ
	h m s			m s	′ ″	h m s	° ′ ″		
Jan. 7	9 13 24	7	3	. . . . . .	−0 9.9	. . . . . .	+40 24 7.1	. . .	n9.602
	9 25 7	7	4*	+0 22.16	. . . . .	4 51 58.55	. . . .	n8.716	. . .
	11 15 1	7	2	. . . . . .	−0 15.6	. . . . . .	+40 24 1.4	. . .	n8.778
	11 23 20	7	2*	+0 21.23	. . . . .	4 51 57.62	. . . .	9.422	. . .
8	8 18 8	7	5*, 4	+0 15.99	+0 4.6	4 51 52.37	+40 24 21.6	n9.322	n9.230
10	11 29 6	7	2*, 4	+0 9.52	+0 51.1	4 51 45.89	+40 25 8.1	9.487	9.230
11	7 4 26	7	3	. . . . . .	+0 54.0	. . . . . .	+40 25 11.0	. . .	9.633
	7 13 50	7	3*	+0 12.03	. . . . .	4 51 48.39	. . . .	n9.528	. . .
12	6 55 52	7	3*, 6	+0 15.57	+0 46.2	4 51 51.92	+40 25 3.2	n9.567	9.568

Mean Places for 1891.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	″	° ′ ″	s	
7	4 51 35.45	+0.94 +0.90	+40 24 12.1	+4.9 +4.4	10^M comp. with W.B. IV, 1151 and 1198

* $\Delta\alpha$ measured direct with the micrometer.

10^M — W.B. IV, 1151, $\Delta\alpha = -2^m\ 14^s.72$ (6). $\Delta\delta = +1'\ 44''.7$ (2)
— W.B. IV, 1198. $\Delta\alpha = -3\ \ 56\ .75$ (6). $\Delta\delta = +0\ \ 34\ .9$ (2)

The $\Delta\delta$ exceedingly difficult to measure at both observations on Jan. 7 and 8.

Mt. Hamilton, 1891 *Jan.* 13.

Observations of Jan. 10, 11 and 12, made with the 36-inch. The comet could not be seen on these dates with the 12-inch, because of its faintness and proximity to the comparison-star. These are a continuation of the observations in *A.J.* no. 232.

ORBIT OF THE COMPANION OF *SIRIUS*,

BY CHARLES P. HOWARD.

The Companion of *Sirius*, being so faint and close, is much of the time lost in the rays of its primary. For this reason accurate measurements are difficult to make, and often simultaneous observations by the best observers, differ widely from each other. When to this is added the fact that since its discovery, the Companion has not completed more than half a revolution, it is clearly as yet impossible to obtain a very exact orbit.

Having tried the graphical method, given in Crossley, Gledhill & Wilson's Hand Book of Double Stars, of interpolating curves, smoothed and adjusted for an elliptic orbit; and finding that the best orbit, to be thus obtained, made the Companion describe much greater yearly areas, from 1862 to 1870, than from 1880 to 1890, I was convinced that, for *Sirius*, no satisfactory orbit could be obtained by this method, but that the best orbit possible to be derived from such scattering observations, could be had graphically by applying directly to the plotted positions, the principle that the Companion in its apparent orbit must describe around *Sirius* equal areas in equal times. To put this method into practice, I proceeded as follows: —

1st. The positions to be plotted were reduced in number by deriving from the observations the average date, position-angle, and distance, for each year. In getting at this average, one good observation was allowed more weight than the average of several poor ones. The position so determined for each year was plotted on a scale of one inch to the second of arc, and marked with its date.

2d. A trial ellipse was then drawn among these positions to average them all as nearly as possible, and the position of the Companion was marked upon it at the two dates which an inspection of the observations indicated as being the most trustworthy. Then, because the Companion describes equal areas in equal times, fixing the place of the Companion for any two instants necessarily fixes its place for every other instant, and its position for any desired series of dates can be marked on the trial ellipse by any convenient method. The Companion's place was therefore marked on the trial ellipse for the date of each plotted position, which by a system of checks could not be in error by more than $\frac{1}{100}$ of an inch. Each calculated and observed position for the same date, was then connected by an arrow, whose direction and length plainly indicated to the eye the discrepancies between them. The systematic discrepancies which then appeared, extending over several years, at once threw light upon the nature of the modifications necessary to be made, to obtain a second trial ellipse that should at least partly correct them.

In this manner successive trial ellipses were drawn, each giving a better orbit than the preceding, until, at the sixth or eighth trial, there still remained systematic differences between the observed and calculated positions, which it seemed impossible to eradicate, and which could perhaps be attributed to some perturbation. I then tried the effect of a slow advance of the periastron in the plane of the true orbit. But this did not change the character of the differences at all; part of them seeming to indicate the revolution of the Companion around a third body, in a plane at right angles to the plane of the apparent orbit, whose pole was perpendicular to the part of the elliptic orbit the Companion was at the time describing. This appearing absurd, I again tried to reduce the discrepancies still further, by continuing the same process as before, until on the eleventh trial all systematic differences disappeared, and there seemed no chance of obtaining a better orbit by carrying the process further.

This gave the following

ELEMENTS OF ORBIT.

Period in years,	57.02
Date of Periastron passage,	1894.17
Inclination,	51° 26′
Position of Node,	40° 45′
Position of Periastron,	48° 35′
Eccentricity,	0.538
Semi-axis Major,	8″.50

The following table gives the observations upon which this orbit is based, with the differences between the observed and calculated positions.

Date	Position Angle		Distance	Nights	Observer	Diff. between observed and calculated C − O	
	At date of observation	Corrected to 1890				Position Angle	Distance
		°	″				
1862.08	85.	85.2	10.	. .	A. Clark	−1.0	−.19
19	84.6	84.8	10.07	. .	Bond	− .9	−.25
20	85.0	85.2	. .	. .	Rutherfurd	−1.[illegible]	. .
20	84.6	84.8	. .	. .	Chacornac	− .9	. .
23	85.0	85.2	10.42	. .	Challis	−1.1	−.37
28	83.4	83.6	. .	1	Lassell	+ .1	. .
1863.14	79.3	79.5	10.6	. .	Marth	+2.[illegible]	−.54
15	79.2	79.4	10.6	3	Mitchell	+2.[illegible]	−.[illegible]1
21	82.5	82.7	10.14	2	O. Struve	−1.[illegible]	−.[illegible]7
23	. .	. .	10.00	1	Dawes	. .	+.08
24	79.7	79.9	. .	. .	Winnecke	+1.[illegible]	. .
27	82.8	83.0	. .		Bond	+ [illegible]	. .
1864.18	80.2	80.4	9.60	2	Lassell	−1.[illegible]	+.7[illegible]
22	79.5	79.7	10.92	2	O. Struve	[illegible]	[illegible]
1865.20	77.2	77.3	10.60	4	O. Struve	[illegible]	[illegible]
22	77.9	78.0	10.78	2	Foster	[illegible]	[illegible]
22	75.5	75.6	9.59	9	Secchi	[illegible]	[illegible]
24	73.7	73.7	10.79	1	Struve	+ [illegible]	[illegible]

Date	Position Angle		Distance	Nights	Observer	Diff. between observed and calculated C—O	
	At date of observation	Corrected to 1890				Position Angle	Distance
		°	″			°	″
1865.25	76.8	76.9	. .	3	Tietjen	— .1	. .
26	76.9	77.0	. .	1	Engelmann	— .2	. .
26	76.0	76.1	9.0	. .	Bond	+ .6	+1.53
1866.08	77.1	77.2	10.43	2	Knott	—2.1	+0.25
20	73.8	73.9	10.97	1	Tietjen	+ .9	— .26
20	. .	. .	10.74	1	Bruhns	. .	— .03
20	75.2	75.3	10.93	. .	O. Struve	— .5	— .22
21	74.3	74.4	10.43	5	Washington	+ .3	+ .28
28	71.3	71.4	10.10	3	Secchi	+3.3	+ .61
1867.22	72.1	72.2	10.98	2	O. Struve	+ .5	— .10
24	72.3	72.4	. .	2	Foster	+ .3	. .
1868.21	69.5	69.6	11.35	. .	Bruhns	+1.1	— .32
26	71.6	71.7	10.95	5	Engelmann	—1.0	+ .08
1869.10	74.7	. .	11.26	4	Brunnow	. .	— .12
15	73.6	. .	11.23	3	Vogel	. .	— .09
20	68.7	68.8	11.17	. .	Dunér	.0	— .03
1871.16	65.9	66.0	10.75	3	Secchi	—1.1	+ .57
22	64.1	64.2	10.92	. .	Dunér	+ .5	+ .40
1872.18	59.8	59.9	11.00	. .	Dunér	+3.0	+ .36
24	62.7	62.8	11.55	11	Washington	+ .1	— .19
1873.22	60.8	60.9	10.57	. .	Dunér	+ .2	+ .79
1874.14	58.0	58.1	11.39	11	Washington	+1.3	— .05
1875.19	57.1	57.2	10.73	. .	Dunér	+ .2	+ .55
23	56.2	56.3	11.47	11	Washington	+1.1	— .19
1876.22	55.2	55.3	11.19	6	Washington	+ .2	.00
1877.21	53.1	53.2	11.15	10	Washington	+ .2	— .10
93	53.2	53.3	10.71	5	Burnham	—1.1	+ .22
1878.03	51.1	51.2	10.06	3	Burnham	+ .6	+ .84
24	51.7	51.8	10.76	5	Washington	— .3	+ .10
1879.20	50.1	50.2	10.55	6	Washington	— .7	+ .10
75	46.5	46.6	10.29	. .	Cincinnati	+1.6	+ .21
1881.26	45.3	45.4	10.00	. .	Washington	— .4	+ .05
1882.20	42.3	42.3	9.81	Ave	Washington	+ .2	— .12
1883.10	40.1	. .	9.05	10	Burnham	.0	+ .24
10	39.0	. .	9.41	. .	Young	+1.1	— .12
12	39.7	. .	9.02	11	Hough	+ .3	+ .26
19	40.2	. .	9.50	13	Washington	— .4	— .25
1884.05	36.0	. .	9.67	. .	Hough	+1.3	— .85
17	36.7	. .	8.81	. .	Hough	+ .3	— .05
19	36.4	. .	8.39	. .	Burnham	+ .5	+0.36
1884.23	37.7	. .	8.81	. .	Washington	—1.0	—0.08
27	36.3	. .	8.70	. .	Paris	+ .4	+ .02
1885.11	34.1	. .	8.09	. .	Paris	— .2	+ .15
20	32.7	. .	7.96	. .	Hough	+1.0	+ .23
26	34.9	. .	8.08	8	Hall	—1.5	+ .07
1886.18	30.8	. .	7.30	Ave	Washington	—1.0	+ .25
22	30.1	. .	7.38	6	Hall	— .5	+ .14
1887.14	25.4	. .	7.08	. .	Young	— .2	— .25
23	24.2	. .	6.51	4	Hall	+ .6	+ .31
1888.25	23.3	. .	5.78	3	Hall	—4.4	+ .19
1888.97	14.0	. .	5.28	. .	Burnham	— .7	+ .05
1890.27	359.7	. .	4.19	3	Burnham	— .5	—0.06

How near this comes to being the true orbit, will in a few years be made apparent, by the agreement of the observed positions, with the following

EPHEMERIS

Year	Jan. 1		March 15	
	Position Angle	Distance	Position Angle	Distance
	°	″	°	″
1891	347.2	3.49	342.8	3.33
2	321.9	2.81	315.6	2.73
3	288.0	2.67	281.8	2.72
4	259.8	3.07	255.3	3.21
5	238.9	3.74	235.7	4.87
6	223.8	4.34	221.4	4.44
7	212.2	4.76	209.9	4.83
8	202.1	5.02	200.6	5.05
9	193.0	5.17	191.2	5.19
1900	184.1	5.28	182.4	5.30
1	175.7	5.36	174.0	5.37
2	167.4	5.46	165.8	5.47
3	159.5	5.56	158.0	5.59
4	151.8	5.70	150.4	5.73
5	144.9	5.87	143.6	5.90

The following table gives the position of the Companion for some of the cardinal points of its apparent orbit.

	Date	Posit. Angle	Distance
		°	″
Nearest apparent approach	1892 Sept. 14	298.7	2.64
Companion West of Sirius	1983 Aug. 15	270.0	2.87
" South "	1900 July 10	180.0	5.32
" East "	1917 June 20	90.0	9 22

Hartford, Conn., 1891 *Jan.* 26.

FILAR-MICROMETER OBSERVATIONS OF COMET *e* 1890 (*ZONA, Nov. 15*),

MADE WITH THE 12-INCH EQUATORIAL OF THE LICK OBSERVATORY,

BY E. E. BARNARD.

(Continued from Nos. 230-232.)

Mt. Hamilton M.T. 1890-91	*	No. Comp.	☄—* Δα	☄—* Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for	log pΔ for
			m s	′ ″	h m s	° ′ ″		
Dec. 9 8 0 11	5	12 . 6	—1 0.57	+3 39.8	3 19 9.48	+34 6 32.9	*n*9.441	9.996
Jan. 9 10 23 24	6	10 . 6	—2 2.93	+2 40.8	1 49 46.29	+28 1 59.2	9.650	0.462

Mean Places for 1890.0 and 1891.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
5	3 20 6.45	+3.62	+34 2 36.9	+16.2	W.B. III. 373
6	1 51 48.27	+0.98	+27 59 15.4	+ 3.0	W.B. I, 1168

Dec. 9. Comet ½′ in diameter. R; gbM. to an ill-defined nucleus.

Jan. 9. Of about 13½ mag., with indefinite brightening in the middle.

The comet will not perhaps be observable after the present moon withdraws.

Mt. Hamilton, 1891 *Jan.* 14.

FILAR-MICROMETER OBSERVATIONS OF COMET *e* 1890 (*ZONA*),

MADE AT THE OBSERVATORY OF THE STATE UNIVERSITY OF MISSOURI,

BY MILTON UPDEGRAFF.

1890 Columbia M.T	*	No. Comp.	☄—* Δα	☄—* Δδ	☄'s apparent α	☄'s apparent δ	log pΔ for	log pΔ for
h m s			m s	′ ″	h m s	° ′ ″		
Dec. 8 8 45 5.1	1	6	—0 23.28	—1 34.9	3 24 13.54	+34 16 53.2	*n*9.3181	9.9908
10 7 44 52.2	2	12	+0 42.51	0 0.0	3 14 51.3	+33 56.1	*n*9.4742	0.1291
11 7 46 38.7	3	5	—0 33.14	+2 45.7	3 10 16.06	+33 45 54.0	*n*9.1440	[illegible]
13 8 56 36.5	4	8	+1 56.31	+0 50.9	3 1 18.11	+33 21 51.5	*n*8.8976	9.9120

Mean Places for 1890.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	3 24 33.18	+3.64	+34 18 11.6	+16.5	W.B. III, 417
2	3 11 5.2	+3.60	+33 55.8	+17.3	Bonn DM.
3	3 10 15.63	+3.57	+33 12 50.8	+17.5	W.B. III, 178
4	2 59 18.30	+3.50	+33 20 12.2	+18.4	Paris Catalogue

In making the above observations the instruments used were a 7½-inch equatorial telescope and micrometer by MERZ und MAHLER, and a sidereal clock and chronograph, both by FAUTH & Co. The position of the observatory is approximately

$\lambda = 6^h\ 9^m\ 18^s$ (Greenwich) [illegible]

The places of the comparison-stars have been kindly furnished by the Director of the Washburn Observatory.

EPHEMERIS OF COMET 1889 V,

By WILLIAM BELLAMY.

The praiseworthy efforts, for which the thanks of astronomers are due to Mr. Barnard, to continue the observation of this exceedingly difficult object, have again been attended with success. He succeeded in getting another position, on January 12, and writes that he hopes certainly to get it again in February and perhaps in March. This is not unlikely, as the brightness then will be only a third less, theoretically, than at the time of his January observation. I therefore continue the ephemeris given in No. 230 for the period after the waning of the February moon. In that number I employed the elements of Mr. Poor, as the best then available. But the publication, two months ago, of Mr. Chandler's elements (No. 231) gives the means for an ephemeris practically without any error, the deviation therefrom of Barnard's subsequent observations being less than 1^s in α, and $10''$ in δ, while those of Bauschinger in *A.N.* 3013, this day received, show deviations of 6^s or 7^s in α, and half a minute in δ, — exceeding those of Poor's elements, published last November (*A.J.* 228). It is interesting to note that this comet has now been followed through an arc of 156° of heliocentric motion, all lying outside the earth's orbit, and to a heliocentric distance of 3.75 and a geocentric distance of 2.80, which for so faint an object is unexampled.

Dorchester, Mass., 1891 *Feb.* 1.

The equatorial constants, for the equinox and ecliptic of 1891.0, are as follows:

$$\begin{aligned} x &= (9.9997680)\ r \sin(\ 91^\circ\ 29'\ 59''.78+v) \\ y &= (9.9409206)\ r \sin(\ \ 2\ 32\ 50.24+v) \\ z &= (9.6891419)\ r \sin(358\ \ 9\ 30.45+v) \end{aligned}$$

Ephemeris.

Gr. M.T.	App. α	App. δ	log Δ	Br.
	h m s	° ′ ″		
1891 Feb. 27.5	8 3 17.1	+27 45 16	0.49836	.061
28.5	3 21.9	44 39		
Mar. 1.5	2 57.3	43 58		
2.5	2 33.7	43 13		
3.5	2 11.2	42 24	0.50619	.058
4.5	1 49.9	41 31		
5.5	1 29.8	40 34		
6.5	1 10.9	39 33		
7.5	0 53.2	38 29	0.51429	.056
8.5	0 36.8	37 20		
9.5	0 21.6	36 7		
10.5	8 0 7.6	34 51		
11.5	7 59 54.8	33 31	0.52261	.053
12.5	59 43.3	32 8		
13.5	59 33.0	30 41		
14.5	59 23.8	29 11		
15.5	7 59 15.8	+27 27 37	0.53110	.051

CORRIGENDA.

No. 231, p. 117, col. 1, last table, 2d heading, *for* maxima *put* minima. Corrected erroneously on p. 128.
p. 120, col. 1, line 13, *for* diminished *put* increased.

No. 232, p. 126, in observations of Comet *e* 1890 Dec. 11,		$\Delta\delta$	δ		$\Delta\delta$	δ
		′ ″	° ′ ″		′ ″	° ′ ″
	for	−1 54.6	+33 47 33.0	*put*	−4 19.8	+33 45 7.8
		+4 19.8	+33 47 27.6		+1 54.6	+33 45 2.4

No. 233, p. 130, col. 2, line 10 from below, *for* r *put* r^2.
" p. 132, col. 1, line 7 from below, *for* two years *put* three years.
No. 234, p. 140, col. 1, line 21, and col. 2, line 10, *for* personal equation *put* probable error.
" p. 142, col. 2, line 11 from below, *for* *f* *put* I.
" p. 144, col. 1, 2d title, *for* Edward *read* Edmund.

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On the Mean and Secular Motion of the Moon's Perigee, by Prof. John N. Stockwell.
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Filar-Micrometer Observations of Comet *e* 1890, by Prof. Milton Updegraff.
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DEFINITIVE ORBITS OF THE COMPANIONS OF COMET 1889 V.

By S. C. CHANDLER.

I.

1. The vicissitudes in the history of this comet give it an interest exceeded, perhaps, by no other in astronomical annals; and the settlement of the problems connected therewith promises to illuminate our knowledge of cometary mechanics in various important particulars.

While the manner in which the comet became separated into several parts, by its encounter with *Jupiter* in 1886, may possibly require for its precise exposition the observations which will be obtained at the next appearance in 1896, we may hope for an approximate answer in the careful discussion of those made in 1889 alone. It is therefore proposed in the present paper to establish, as accurately as this material will permit, the orbits of the companions relative to that of the main comet in 1889; and in a subsequent paper to trace these paths back through *Jupiter's* system in 1886, and show, if practicable, how the action of *Jupiter* and his fourth satellite operated to produce the rupture.

2. To begin with, it is necessary to notice some of the physical phenomena presented by the companions. The notation used will be the letters assigned by Barnard, B, C, D and E, in order of the distances from the main comet A. As is known, B and C were detected by him on Aug. 1, with the 12-inch, D and E on Aug. 4, with the 36-inch. It is desirable to remark here that the reason for their not having been discovered in the previous month, on July 8, 9 and 10, cannot have been superposition by perspective, at least in the case of C and the more distant companions; for the orbit of C hereinafter deduced shows that such superposition occurred two months previous to discovery of A by Brooks, and gives for July 8 a distance of 190″ at 62°.5 position-angle. That the companions were not seen in July, may be naturally ascribed to interference of moonlight up to about July 20, and after that either to the fact that the attention of observers was not sufficiently directed to the phenomenon, or to the fact that the objects had not yet become bright enough to be easily discernible. We have the evidence of Spitaler that on July 30 and 31 nothing abnormal was noticed with the 27-inch — the slight elongation on those dates, seen by him in A, having no relation to the matter in hand. Two nights after, at the time of discovery, Barnard estimated the brightness of C at about one-fifth that of A. It then gradually increased in brilliancy, also becoming less diffused and developing a strong condensation and nucleus, until at the end of August it was actually brighter than A, although only one-third its size. In early September it was about equal in brightness to A, but from the middle of that month faded, and became larger and more diffuse until it disappeared, late in November. The faint nucleus of B, in the beginning, appears to have been a little brighter than that of C, and its coma smaller and less diffused. About the middle of August it had grown to be larger and fainter than at first, later more rapidly so, being excessively difficult to see or measure in the first few days of September, and invisible immediately thereafter. D and E were measured only on the night of discovery, and were seen only at rare intervals until the last time on Aug. 29.

Such, briefly described, are the main features as to brightness and visibility of these objects. I beg courteously to dissent from the view which has been confidently expressed that the diffusion and disappearance of B, while it was theoretically increasing in brightness, indicate "that it actually dissipated itself into space and absolutely ceased to exist, if indeed it were not absorbed into the main comet." Such a conclusion is inherently improbable, unwarranted by any knowledge we possess as to the process of cometary light-development, and contradicted by inferences drawn from other cases, of which only the most analogous need be cited; namely, that of the two nuclei of Biela's comet, the capricious action of which affords a strict counterpart to the present instance. It will be recollected that fitful alternations of visibility occurred in 1846 and especially in 1852, when they repeated themselves almost from day to day. The two companions were not habitually seen at the same time, but sometimes one, sometimes the other; so that observers could not tell which they were looking at, without comparison with the ephemeris. Thus in the space of one week, for example, 1852 Sept. 15 to 22, both nuclei were visible, then only the southern, then only the northern, then both together, again only the southern, and finally only the northern, on successive nights, respectively.

It may be added that there appears to be little reason for interpreting these remarkable variations of brilliancy as standing in any relation of effect with the cause which produced the disruption, either in **Biela**'s comet or in 1889 V; but much more for supposing that similar behavior may be common, in greater or less degree, escaping attention ordinarily from the difficulty of photometric comparisons in the case of isolated comets, but easily attracting the eye, by contrast, when two objects nearly alike are in the same field.

3. The companion *C* was by far the most continuously and generally observed, and indeed the only one in which there are adequate means for the determination of a satisfactory orbit. With a few exclusions for mistakes or incompleteness, we have 155 positions, covering an interval of 114 days, contributed by 16 observatories. Of these the Lick series, by **Barnard**, constitutes over one-third, begins earlier, ends later, and is more continuous than any other. It has a superior degree of excellence as to smallness of accidental error; and, notwithstanding some small peculiarities that will appear later in the discussion, we may be warranted in assuming that the advantages of exceptional atmosphere and aperture reduce to a minimum the chance for varying systematic error, dependent on the changing aspect of this faint object during its long season of visibility. I have, therefore, unhesitatingly chosen this series as a zero of reference for the constant errors of the other observations, and have also given an independent solution based on the Lick observations alone, for comparison with, and reinforcement of, the conclusions drawn from the general solution. While according it this merited distinction, I may be pardoned for the following remark. For the value of the screw-revolution of the micrometer of the 36-inch, a mean was taken between a determination made by **Keeler** for use in measurement of the satellites of *Mars*, — and described by him as a provisional one, sufficiently accurate for that purpose (*A.J.* VIII,73), — and one by **Burnham**, presumably for use with close double stars. While the accuracy of these is unquestioned, a searching and independent verification of this important constant would secure a control against possible accumulated error over the range of forty or more revolutions employed for the measurement of the companions. The value adopted for the micrometer of the 12-inch was 14″.057, which differs considerably from that given on p. 65, Vol. I, of the Lick Publications (14″.086 ± 0″.010), but may be presumed to be more accurate.

Gr. M.T.		Δα	Δδ	Wt.	C − O		Authority
		s	″		s	″	
Aug.	3.878	+15.54	+126.2	2	+0.07	− 1.7	L : B
	4.928	15.79	127.7	2	− .02	− 1.8	L : B
	5.552	15.15	117.5	1	+ .73	+ 9.1	V : S
	5.859	15.93	129.4	2	.00	− 2.2	L : B
	7.552	16.28	124.3	1	− .07	+ 5.2	V : S
	16.901	17.69	142.9	2	+ .03	− 0.8	L : B
	17.898	17.93	143.4	2	− .05	0.0	L : B
	18.879	18.08	145.2	2	− .05	− 0.6	L : B
	19.553	17.89	146.0	1	+ .21	− 0.6	V : P
	19.873	18.24	145.9	2	− .06	− 0.1	L : B
	20.878	18.42	145.5	2	− .09	+ 1.6	L : B
	21.898	18.59	147.5	2	− .10	+ 0.8	L : B
	22.903	18.68	149.4	2	− .05	+ 0.1	L : B
	23.893	18.82	150.6	2	− .04	+ 0.1	L : B
	24.828	18.98	153.7	2	− .07	− 2.0	L : B
	25.822	19.11	153.5	2	− .06	− 0.6	L : B
	26.447	18.88	151.2	1½	+ .25	+ 2.3	P : R
	26.912	19.10	156.0	2	+ .09	− 2.0	L : B
	27.830	19.24	156.5	2	+ .07	− 1.5	L : B
	28.489	19.29	156.7	1½	+ .11	− 1.0	P : R
	28.507	19.32	156.8	1	+ .08	− 1.1	N : C
	28.855	19.37	156.3	2	+ .07	− .02	L : B
	29.420	19.14	155.8	1	+ .38	+ 0.9	N : C
	29.464	19.38	158.3	1½	+ .14	− 1.6	P : R
	29.536	19.33	156.7	1½	+ .20	+ 0.1	P : B
	29.911	19.52	158.1	2	+ .05	− 1.0	L : B
	30.435	19.49	155.9	1	+ .15	+ 1.8	N : C
	30.456	19.61	156.7	1½	+ .03	+ 1.0	A : R
	30.486	19.59	160.0		+ .05	− 2.3	A : S
	30.488	+19.65	+156.6	1½	0.00	+ 1.1	P : B
Aug.	31.426	+19.66	+158.0	1	+0.10	+ 0.6	N : C
	31.424	19.77	158.0	1½	− .01	+ 0.6	A : S
	31.462	19.52	156.8		+ .24	+ 1.8	A : R
	31.888	19.78	160.9	2	+ .03	− 1.9	L : B
Sept.	1.443	19.60	160.2	1	+ .27	− 0.6	N : C
	1.519	19.73	160.3	1½	+ .15	− 0.7	P : B
	2.448	20.07*	162.0	2	− .09	− 1.5	P : R
	2.465	20.30	158.1	1½	− .32	+ 2.4	A : R
	2.852	19.93	162.8	2	+ .09	− 2.0	L : B
	3.496	20.32	162.7	1	− .23	− 1.4	A : R
	3.839	20.18	162.2	2	− .06	− 0.6	L : B
	4.599	19.82	162.5	1	+ .38	− 0.3	A : R
	4.886	20.27	162.8	2	− .04	− 0.3	L : B
	4.923	20.20	161.0	1	+ .03	+ 1.5	L : B(12)
	5.530	20.18	161.5	1	+ .11	+ 1.5	N : C
	5.889	20.39	162.5	1	− .07	+ 0.7	L : B(12)
	5.942	20.41	163.4	2	− .09	− 0.1	L : B
	6.637	21.03	160.0	1	− .65	+ 3.8	A : R
	14.347	20.92	166.3	1	− .04	+ 1.8	A : R
	14.381	20.69	172.4	1	+ .19	− 4.3	M : B
	14.847	21.02	167.5	2	− .09	+ 0.8	L : B
	15.356	20.88	168.0	2	+ .04	+ 0.4	P : R
	15.385	20.43	162.9	1	+ .49	+ 5.5	M : B
	15.737	21.11	166.9	2	− .18	+ 1.7	L : B
	16.389	20.86	165.7	1	+ .09	+ 3.1	M : B
	16.411	20.82	172.5	0	+ .13	− 3.7	O : P
	16.790	20.96	168.5	2	.00	+ 0.4	L : B
	17.354	20.88	162.4	1	+ .09	+ 6.6	M : B
	17.372	20.95	170.3	2	+ .02	− 1.3	P : R
	17.411	+20.95	+175.3	0	+0.02	− 6.3	O : P

Gr. M.T.	Δα	Δδ	Wt.	C — O		Authority
	s	″		s	″	
Sept. 17.468	+18.39	+149.6	0	+2.58	+ 19.5	P : K
17.471	20.83	168.7	1	+0.14	+ 0.4	S : B
17.488	21.27	170.4	1	— .30	— 1.3	L : C
17.757	20.94	169.0	2	+ .04	+ 0.2	L : B
18.361	21.10	168.6	1	— .11	+ 0.7	S : B
18.385	20.89	170.2	2	+ .10	— 0.9	P : R
18.401	21.16	167.8	1	— .17	+ 1.5	A : R
18.411	20.59	179.3	0	+ .40	— 10.0	O : P
18.487	20.95	165.7	½	+ .04	+ 3.6	P : K
18.724	20.99	168.8	2	+ .01	+ 0.6	L : B
19.435	21.03	167.1	1	— .03	+ 2.4	M : B
19.778	21.09	170.3	1	— .09	— 0.7	L : B(12)
19.830	21.00	169.5	2	.00	+ 0.1	L : B
20.419	20.89	166.0	1	+ .12	+ 3.7	M : B
20.474	20.90	180.7	0	+ .11	— 11.0	O : P
20.846	21.03	170.5	2	— .02	— 0.8	L : B
21.327	21.01	165.0	1	.00	+ 4.8	M : B
21.386	20.96	168.9	1	+ .05	+ 0.9	A : R
21.759	20.90	171.6	2	+ .10	— 1.8	L : B
22.343	21.05	171.7	2	— .05	— 1.8	P : R
22.411	20.68	182.8	0	+ .32	— 12.9	O : P
22.465	20.57	174.1	1	+ .43	— 4.2	*P : A*
22.752	20.95	170.6	2	+ .04	— 0.7	L : B
23.337	20.78	173.5	1	+ .21	+ 3.6	M : B
23.372	21.20	174.7	1	+ .21	— 4.8	A : R
23.473	21.56	169.1	½	— .57	+ 0.8	D : E
23.740	20.90	168.7	2	+ .08	+ 1.2	L : B
24.339	21.04	169.9	2	— .08	0.0	P : R
24.346	20.51	166.3	1	+ .45	+ 3.6	M : B
24.350	20.85	169.9	1	+ .11	0.0	A : R
24.379	20.87	170.1	1	+ .09	— 0.2	*M : B*
24.396	20.92	167.7	1	+ .04	+ 2.2	*P : A*
24.862	20.92	171.1	2	+ .03	— 1.2	L : B
25.379	20.89	183.0	0	+ .05	— 13.2	O : P
25.428	20.92	172.0	1	+ .02	— 2.2	*P : A*
25.468	21.01	175.8	1	— .07	— 6.0	B : R
25.831	20.89	171.3	2	+ .04	— 1.5	L : B
26.346	20.74	166.8	1	+ .17	+ 2.9	M : B
26.434	20.68	165.9	½	+ .23	+ 3.8	P : K
26.535	20.69	176.3	1	+ .21	— 6.6	B : R
26.863	20.85	171.3	2	+ .01	— 1.6	L : B
27.318	20.57	165.8	1	+ .30	+ 3.8	M : B
27.383	20.52	476.7	0	+ .35	—307.1	B : C
27.389	20.82	170.5	1	+ .05	— 0.9	*P : A*
27.410	20.83	171.1	1	+ .04	— 1.5	*M : B*
27.715	20.89	170.1	2	— .03	— 0.6	L : B
28.361	20.28	178.2	1	+ .55	— 8.8	M : B
28.381	+21.11	+173.3	1	—0.28	— 3.9	A : R
Sept. 28.895	+20.79	+169.3	2	+0.01	0.0	L : B
29.727	20.70	169.3	2	+ .06	— 0.2	L : B
30.379	20.66	181.2	0	— .34	— 12.2	O : P
30.707	20.73	168.8	2	— .03	+ 0.1	L : B
Oct. 1.413	20.13	162.0	1	+ .23	+ 6.7	M : B
1.474	20.76	184.1	0	— .10	— 15.4	O : P
1.707	20.59	169.1	2	+ .05	— 0.5	L : B
2.393	20.71	167.3	2	— .11	+ 1.1	P : R
2.425	20.40	167.5	1	+ .20	+ 0.9	M : B
3.377	20.43	166.0	2	+ .10	+ 2.0	P : R
3.506	20.67	168.4	1	— .15	— 0.4	*P : A*
4.713	20.44	168.6	2	— .01	— 1.1	L : B
10.672	19.99	163.7	2	— .07	+ 1.1	L : B
11.708	19.71	161.0	2	+ .07	0.0	L : B
14.385	19.65	161.8	1½	— .17	+ 0.6	P : R
14.754	19.38	163.4	2	+ .06	— 1.2	L : B
15.369	19.41	154.4	1	— .04	+ 7.4	*M : B*
15.741	19.32	160.9	2	+0.01	+ 0.6	L : B
17.309	19.15	154.1	1	.00	+ 6.3	M : B
17.452	20.75	167.7	0	—1.61	— 7.4	O : P
18.531	18.46	160.2	1	+0.54	— 0.6	C : W
19.378	18.91	164.3	0	— .01	— 5.5	O : P
19.446	18.89	161.4	1	.00	— 2.5	S : B
21.436	18.56	158.1	1½	+ .08	— 0.6	A : R
21.484	18.28	166.9	0	+ .35	— 9.4	O : P
22.372	18.94	133.7	0	— .42	+ 23.0	P : A
22.388	18.39	159.0	1½	+ .13	— 2.3	A : R
23.326	18.12	153.5	1	+ .28	+ 2.5	M : B
23.386	18.80	154.0	1	— .40	+ 2.0	V : S
23.586	17.73	156.9	1	+ .64	— 1.1	C : W
23.724	18.28	156.4	2	+ .07	— 0.4	L : B
24.276	18.26	150.1	1½	+ .02	+ 4.9	P : R
24.386	18.40	153.8	1	— .14	+ 1.4	V : S
24.452	18.24	161.9	0	+ .01	— 6.7	O : P
24.748	18.27	153.5	2	— .06	+ 1.4	L : B
27.309	18.01	153.9	2	— .15	— 1.0	P : R
28.701	17.65	153.3	2	+ .06	— 1.5	L : B
30.709	17.42	149.3	2	+ .02	+ 0.8	L : B
Nov. 10.636	16.05	141.2	2	+ .01	— 0.3	L : B
11.622	15.88	141.9	2	+0.05	— 1.8	L : B
12.285	14.37	141.0	0	+1.48	— 1.5	O : P
13.629	15.71	139.3	2	—0.02	— 1.0	L : B
14.601	15.19	135.9	1	+ .39	+ 1.6	C : W
15.527	15.40	142.0	1	+ .07	— 5.3	C : W
16.527	15.07	139.4	1	+ .28	— 3.6	C : W
24.656	14.22	126.1	2	+ .22	+ 2.8	L : B
25.704	+14.18	+125.4	2	—0.15	+ 2.6	L : B

4. The above table contains the observations of the companion *C* referred to *A*, expressed in differences of right-ascension and declination, in the sense *C* — *A*; omitting only a few cases which were incomplete, or which were merely estimates, or which were indicated by the observer as uncertain. The times are corrected for aberration. At Pulkowa, Paris and Lick, distances and position-angles were observed; at the other observatories R.A. and Decl. differences, generally with the filar micrometer, but at Cambridge with the square-bar. The published coordinates for Paris and Lick have been converted into the adopted system; those for Pulkowa were already so given by the observer. Corrections for the proper motion of the comet have been applied to the observed differences where the comparisons with it and the companion were not simultaneous.

The system of weights is described in section 6. The residuals C—O are the comparisons with the preliminary ephemeris given in section 5. The authority is indicated by two initials, the first being that of the observatory, the second that of the observer, thus:

Symbol	Observatory	Observer	No. obs.
A : R	Algiers	Rambaud	14
A : S	Algiers	Sy	2
B : C	Bordeaux	Courty	1
B : R	Bordeaux	Rayet	2
C : W	Cambridge	Wendell	5
D : E	Dresden	v. Engelhardt	1
L : B	Lick	Barnard (36-inch)	54
L : B (12)	Lick	Barnard (12-inch)	3
L : C	Lyons	Le Cadet	1
M : B	Marseilles	Borrelly	16
M : *B*	Munich	Bauschinger	3
N : C	Nice	Charlois	6
O : P	Orwell Park	Plummer	13
P : A	Palermo	Agnello	1
P : *A*	Padua	Abetti	5
P : B	Paris	Bigourdan	3
P : K	Paris	Klumpke	3
P : R	Pulkowa	Renz	14
S : B	Strassburg	Becker	3
V : P	Vienna	Palisa	1
V : S	Vienna	Spitaler	4

5. To obtain a preliminary ephemeris for comparison with the observations I computed a provisional set of differences of the elements of A and C, by processes precisely similar to those by which the definitive system hereafter given were derived. Instead of applying these to the elements of A to get those of C, and calculating from both sets the places of the two components, I arranged the following formulas, which give the desired differential ephemeris, by a single five-place computation, with much greater accuracy and one-third the labor of the double seven-place computation by the ordinary methods.

$$s \sin S = r \sin a \cos(A+v)\, du + \sin a \sin(A+v)\, dr$$

$$s \cos S = r \sin b \cos(B+v)\, du + \sin b \sin(B+v)\, dr$$

$$\Delta\alpha = \frac{s \cos(S+\alpha)}{\Delta \cos\delta}$$

$$\Delta\delta = -\frac{s \sin(S+\alpha)}{\Delta} \sin\delta + \frac{\cos\delta}{\Delta}\Big[r \sin c \cos(C+v)\, du + \sin c \sin(C+v)\, dr \Big]$$

Adopting from the provisional solution above mentioned, $\Delta T = -^{d}.2235$, $\Delta\omega = -172''.5$, $\Delta q = -.000471$, and putting the other differences $= 0$, we find, from the partial differentials of u and r with reference to T, ω and q, the values of du and dr for use in the above formulas.

$$du = (3.12810)\frac{1}{r^2} + (0.33783)\frac{t-T}{r^2} - 172''.50$$

$$dr = (2.34322) \sin v + (9.55295) \sin v (t-T) + (n1.69735) r$$

the coefficients being logarithmic. The other quantities needed were found from my elements on p. 101, Vol. IX, after referring them to 1889.0, as follows:

$$T = 1889 \text{ Sept. } 30.0119 \text{ Gr.}$$

$$\begin{array}{rlrl}
\omega = & 343^\circ\ 27'\ 30''.0 & A = & 91^\circ\ 19'\ 47''.57 \\
\Omega = & 17\ \ 57\ \ 57\ .0 & B = & 2\ \ 22\ \ 31\ .26 \\
i = & 6\ \ \ 4\ \ 10\ .0 & C = & 357\ \ 59\ \ 38\ .95 \\
\log a = & 0.5664000 & \log \sin a = & 9.9997689 \\
\log e = & 9.96727478 & \log \sin b = & 9.9409240 \\
\log q = & 0.2900986 & \log \sin c = & 9.6894273
\end{array}$$

To the ephemeris so obtained were added $+0^{s}.017$ and $+0''.18$, determined as the correction for the non-linear character of the relations between the differences of the elements and those of the geocentric places. Strictly this correction is not constant for the whole interval, but the error of assuming it to be so is not over $0^{s}.003$ and $0''.03$ in any case. The differential reduction from mean to apparent equinox in no case exceeds $0^{s}.001$ and $0''.01$.

The ephemeris was interpolated to single days; it is sufficient here to give it for each third day. Its comparison with the observations is given in the columns C—O in the foregoing section, and shows that these provisional elements must be extremely close to the definitive values.

EPHEMERIS FOR GREENWICH NOON.

1889	$\Delta\alpha$ s	$\Delta\delta$ ″	1889	$\Delta\alpha$ s	$\Delta\delta$ ″
Aug. 1	+15.131	+120.48	Oct. 3	+20.555	+168.17
4	15.623	124.65	6	20.322	166.98
7	16.118	128.80	9	20.050	165.53
10	16.611	132.91	12	19.745	163.86
13	17.100	136.95	15	19.414	162.00
16	17.580	140.91	18	19.062	159.98
19	18.049	144.75	21	18.693	157.81
22	18.502	148.43	24	18.312	155.52
25	18.933	151.93	27	17.924	153.15
28	19.336	155.20	30	17.534	150.70
31	19.706	158.21	Nov. 2	17.145	148.21
Sept. 3	20.039	160.92	5	16.760	145.69
6	20.330	163.32	8	16.381	143.11
9	20.573	165.36	11	16.010	140.58
12	20.765	167.04	14	15.647	138.00
15	20.903	168.33	17	15.295	135.43
18	20.985	169.23	20	14.954	132.87
21	21.007	169.75	23	14.623	130.32
24	20.974	169.89	26	14.303	127.75
27	20.885	169.65	29	+13.992	+125.19
30	+20.744	+169.07			

6. The constant errors were investigated by using the Lick series as a system of reference, for the reasons stated in section 3. For this purpose the following table of corrections was computed, by means of the elements deduced from the Lick observations alone, in section 8.

	s	″		s	″
Aug. 5	+0.019	+0.70	Oct. 4	—0.001	+0.05
15	.013	.61	14	.008	—0.09
25	.009	.52	24	.016	.20
Sept. 4	.007	.37	Nov. 3	.023	.27
14	.006	.29	13	.030	.33
24	+0.004	+0.18	23	—0.038	—0.37

The corrections interpolated from this table were applied to the values of C—O in section 4, and the results for the separate observatories assembled. Their mean values and probable errors are given below in the third and fourth columns. Subtracting these from the individual residuals, the outstanding quantities may be regarded as purely accidental, and give the probable errors of a single observation as in the fifth column. By means of this table, and certain general considerations which need not be particularized, the systematic corrections and weights were adopted as in the last two columns.

The results given show, as was naturally to be expected, decided personal differences between the right-ascensions deduced from transits and those from position-angles and distances; such are especially noticeable in the Cambridge results, and less so, but still distinct, at Marseilles and Nice. It is also manifest that in the earlier observations, when the companion was very faint, the same point of its figure was not taken for bisection at Vienna and at Lick. Unfortunately the former series is not numerous enough to settle certainly the nature of the systematic difference.

The observations of both *B* and *C* suggest its want of constancy, and I have felt at liberty to modify slightly the first normal place in R.A. on this account, although from its small weight the effect on the solution is quite trivial.

Authority	No. obs.	Systematic difference and probable error. in α		in δ		Prob. error single obs in α	in δ	Adopted correction in α	in δ	Wt. by no. of comparisons 1—5,	5—10,	10+
		s	s	″	″	s	″	s	″			
Lick (36)	54	. . . . .	. . . . .	. . . . .	. . . . .	±0.048	±0.80	0.00	0.0	2		
Lick (12)	3	. . . . .	. . . . .	. . . . .	. . . . .	. . . . .	. . . . .	.00	.0	1		
Pulkowa	14	+0.011	±0.024	+ 0.35	±0.32	± .087	±1.21	.00	.0	1½	2	
Paris (B)	3	+ .127		+ 0.63		. . . . .	. . . . .	.00	0.0	1½		
Vienna	5	+ .074	± .134	+ 3.80	±1.24	± .299	±2.81	+ .27 .00	+2.0	1		
Strassburg	3	+ .013		— 0.30		. . . . .	. . . . .	.00	0.0	½		
Algiers	16	— .048	± .042	+ 0.01	±0.41	± .167	±1.63	.00	.0		1	1½
Nice	6	+ .192	± .033	+ 0.97	±0.32	± .080	±0.78	+ .12	0.0	1		
Marseilles	16	+ .210	± .029	+ 2.40	±0.73	± .116	±2.91	+ .20	+1.5	1		
Cambridge	5	+ .360	± .069	— 2.02	±0.82	± .155	±1.83	+ .36	—2.0	1	1½	
Padua	5	+ .078	± .064	— 0.94	±0.69	± .143	±1.55	0.00	0.0	1		
Munich	3	+ .027		+ 1.97		. . . . .	. . . . .	. . . . .	. . . . .	1	1	
Palermo	1	— .43		+22.9		. . . . .	. . . . .	. . . . .	. . . . .	0		
Dresden	1	— .57		+ 1.0		. . . . .	. . . . .	. . . . .	. . . . .	½		
Lyons	1	— .29		— 1.0		. . . . .	. . . . .	. . . . .	. . . . .		1	
Bordeaux	2	+ .07		— 0.6		. . . . .	. . . . .	. . . . .	. . . . .		1	
Paris (K)	2	+ .14		+ 3.9		. . . . .	. . . . .	. . . . .	. . . . .	½		
Orwell Park	13	+0.058	±0.123	— 8.79	±0.73	±0.443	±2.61	. . . . .	. . . . .	0		

7. The following normal differences were then formed, according to the groupings indicated in the table of observations in section 4.

Date	p	$\Delta\alpha$	$\Delta\delta$	$\cos\eta\, d\theta$	$d\eta$
		s	″	″	
Aug. 5.0	8	+15.757	+126.18	—0.34	+0.24
19.0	13	18.080	144.81	+0.43	—0.17
28.0	28	19.283	155.38	—0.61	+0.55
Sept. 3.0	21½	20.073	161.03	+0.50	—0.14
17.0	29	20.992	168.41	+0.11	—0.67
23.0	27½	20.972	170.49	+0.01	+0.66
30.0	27	20.724	169.59	—0.01	+0.60
Oct. 16.0	16½	19.291	160.82	—0.36	—0.40
26.0	15½	18.071	153.48	—0.01	—0.53
Nov. 13.0	9	15.796	139.69	+0.78	+0.52
25.0	4	+14.373	+125.90	—1.77	—2.10

The perturbations of *Venus*, *Earth*, *Mars*, *Jupiter* and *Saturn*, which I had already computed for the whole appearance, for the definitive orbit of the main comet, were of an order to warrant the inference that the differential planetary disturbance of the two components is entirely inappreciable. It was deemed advantageous to adopt the plane of the undisturbed orbit of *A* as the plane of reference for the geocentric differences $\Delta\alpha$, $\Delta\delta$. The last two columns above, $\cos\eta\, d\theta, d\eta$, are therefore the deviations (O—C) in this system of coordinates to be satisfied by the corrections to the assumed values of the elements. Referring the plane and major axis of the assumed orbit of *A* (sect. 5) to the equator of 1880.0, we have

$$\omega' = 357°\ 59'\ 39''.0, \quad \Omega' = 3°\ 49'\ 23''.17, \quad i' = 29°\ 17'\ 1[illegible]''.2.$$

We then find the following equations of condition for the longitudes:

$$\begin{array}{rrrrcrr}
 & & & & & {}^{\prime\prime} & p \\
+1.6132\,\Delta\chi' & -49470\,\Delta e & -2530.9\,\Delta T & +44118\,\Delta q & = & -0.34 & 8 \\
+1.8050 & -41150 & -2839.4 & +38244 & = & +0.43 & 13 \\
+1.9175 & -34039 & -3017.8 & +35061 & = & -0.61 & 28 \\
+1.9791 & -28655 & -3115.1 & +33192 & = & +0.50 & 24\frac{1}{2} \\
+2.0539 & -14245 & -3236.1 & +28984 & = & +0.11 & 29 \\
+2\,0493 & -\ 7693 & -3232.2 & +26896 & = & +0.04 & 27\frac{1}{2} \\
+2.0151 & -\ \ \ 6 & -3184.1 & +23890 & = & -0.01 & 27 \\
+1.8478 & +16112 & -2931.7 & +14223 & = & -0.36 & 16\frac{1}{2} \\
+1.7070 & +24688 & -2720.4 & +\ 6828 & = & -0.01 & 15\frac{1}{2} \\
+1.4597 & +37017 & -2327.3 & -10273 & = & +0.78 & 9 \\
+1.3145 & +42060 & -2091.8 & -21897 & = & -1.77 & 4
\end{array}$$

and for the latitudes:

$$\begin{array}{rrrrrrcrr}
 & & & & & & & {}^{\prime\prime} & p \\
+0.0509\,\Delta\chi' & +294.0\,\Delta e & -48.98\,\Delta T & +16332\,\Delta q & -0.7549\,\Delta\Omega' & -0.7568\,\Delta i & = & +0.34 & 8 \\
+0.0400 & +163.0 & -38.91 & +16334 & -0.8576 & -0.6166 & = & -0.17 & 13 \\
+0.0282 & +126.6 & -26.57 & +15243 & -0.9162 & -0.5509 & = & +0.55 & 28 \\
+0.0194 & +109.0 & -17.02 & +13984 & -0.9487 & -0.4766 & = & -0.14 & 24\frac{1}{2} \\
+0.0014 & +\ 53.1 & +\ 2.30 & +\ 9548 & -0.9947 & -0.2752 & = & -0.67 & 29 \\
-0.0030 & +\ 24.9 & +\ 6.54 & +\ 7165 & -0.9988 & -0.1816 & = & +0.66 & 27\frac{1}{2} \\
-0.0045 & 0.0 & +\ 7.12 & +\ 4254 & -0.9918 & -0.0711 & = & +0.60 & 27 \\
+0.0046 & +\ 20.2 & -\ 6.13 & -\ 1965 & -0.9297 & +0.1662 & = & -0.40 & 16\frac{1}{2} \\
+0.0117 & +\ 80.4 & -18.70 & -\ 4974 & -0.8696 & +0.2928 & = & -0.53 & 15\frac{1}{2} \\
+0.0296 & +119.0 & -34.60 & -\ 8305 & -0.7458 & +0.4683 & = & +0.52 & 9 \\
+0.0350 & +\ 52.8 & -37.93 & -\ 9179 & -0.6625 & +0.5500 & = & -2.10 & 4
\end{array}$$

A casual inspection of these equations shows that the coefficients of $\Delta\chi'$ and ΔT are related by a nearly constant factor of about -1583 for the longitudes, and of about -1000 for the latitudes. Although these factors are so different, the latitude coefficients are so small relatively, that the numerical indeterminateness of the solution is not thereby much relieved. The elimination was therefore arranged to determine the other five elements in terms of T. Putting, for convenience, $x = \Delta\chi'$, $y = 0.0001\,\Delta e$, $z = 0.001\,\Delta T$, $u = 0.0001\,\Delta q$, $w = \Delta\Omega'$. $w = \Delta i'$. the normal equations are,

$$\begin{array}{rrrrrrcr}
+\ 737.295x & -\ 425.137y & +\ 989.814t & -\ \ 2.327u & -\ 1.012w & -1163.707z & = & -\ 4.875 \\
-\ 425.137 & +1318.053 & -1129.836 & -\ \ 1.409 & -\ 0.587 & +\ 665.645 & = & -\ 5.572 \\
+\ 989.811 & -1129.836 & +1856.804 & -140.570 & -83.795 & -1557.461 & = & +31.438 \\
-\ \ \ 2.327 & -\ \ \ 1.409 & -\ 140.570 & +175.073 & +40.726 & +\ \ \ 2.052 & = & -10.524 \\
-\ \ \ 1.012 & -\ \ \ 0.587 & -\ \ 83.795 & +\ 40.726 & +32.289 & +\ \ \ 0.834 & = & -12.511 \\
-1163.707 & +\ 665.615 & -1557.461 & +\ \ 2.052 & +\ 0.834 & +1836.790 & = & +\ 7.835
\end{array}$$

the solution of which gives,

$$\begin{aligned}
x &= -0.155128 + 1.582953\,z \\
y &= +0.062214 + 0.004050\,z \\
t &= +0.137624 - 0.001666\,z \\
u &= +0.080314 + 0.005392\,z \\
w &= -0.135375 + 0.011213\,z
\end{aligned}$$

The value of z which makes $[nn.6]$ a minimum, is $+8.3$, whence

$$\begin{array}{ll}
x = +13.0 & u = +0.125 \\
y = +\ 0.095 & w = -0.042 \\
t = +\ 0.124 &
\end{array}$$

expressing which in terms of the elements, and adding to the assumed values, we have, since $\Delta\omega' = \Delta\chi' - \cos i'\ \Delta\Omega'$, the differences of the elements of A and C, with their probable errors,

$$\begin{array}{llll}
\Delta T = & -0^{d}.2152 & \pm 0.0141 & \\
\Delta\omega' = & -159^{\prime\prime}.50 & \pm 22^{\prime\prime}.25 & +\ \ 1582.95\ dT \\
\Delta e = & +0.0000095 & \pm 0.0000195 & +0.0004050\ dT \\
\Delta q = & -0.0001586 & \pm 0.0000364 & -0.0001666\ dT \\
\Delta\Omega' = & +0^{\prime\prime}.12 & \pm 0^{\prime\prime}.20 & +\ \ \ \ \ 5.392\ dT \\
\Delta i' = & -0^{\prime\prime}.04 & \pm 0^{\prime\prime}.89 & +\ \ \ \ 11.213\ dT
\end{array}$$

It will be seen that the differences in e, Ω' and i', are evanescent, and much below their probable errors. The truth of this curious result is independent of the indeterminateness, to a moderate amount, in T; for. assuming a possible error in the latter of five times its probable error, in either direction, the corresponding difference in the nodes of the components A and C will lie between $-0^{\prime\prime}.26$ and $+0^{\prime\prime}.50$; that of the inclinations between $-0^{\prime\prime}.84$ and $+0^{\prime\prime}.72$; and that of the eccentricities between -0.0000189 and $+0.000379$; quantities which are below the capacity of the observations to distinguish.

The discussion, therefore, establishes the important proposition that the force which led to the separation of the components A and C, whatever its nature, operated in the plane of the comet's orbit, and produced no change in that plane or in the form of the conic section, but only in its size, and in the direction of its major axis.

We are authorized, in view of this conclusion, to disregard the nominal differences in the node, inclination and eccentricity, and to adopt the results of a solution in which these are assumed to be zero. Thus we obtain from the foregoing normal equations, on this hypothesis,

$$x = -0.1032 + 1.59058\,z, \qquad t = +0.07194 - 0.00911\,z,$$

and, to reduce $[nn.3]$ to a minimum, $z = -8.6$. Consequently we have as the definitive values of the differences of the elements of A and C,

$$\text{II}\left\{\begin{aligned} \Delta T &= -0^{\text{d}}.2321 \\ \Delta\omega = \Delta\omega' &= -186''.28 \; +1590.58\; dT \\ \Delta q &= -0.000456 - 0.000911\,dT \end{aligned}\right.$$

from which we find $[pvv] = 107.72$. The solution (I), with six unknowns, gave 104.83. The difference is merely nominal. The deviation O—C of both hypotheses from the normal places is here added, for comparison.

	$\cos\eta\, d\theta$		$d\eta$	
	I	II	I	II
	″	″	″	″
Aug. 5	−0.39	−0.55	−0.06	+0.37
19	+0.45	+0.31	−0.19	−0.20
28	−0.60	−0.66	+0.31	+0.49
Sept. 3	+0.49	+0.49	−0.32	−0.23
17	+0.04	+0.15	−0.71	−0.77
23	−0.03	+0.07	+0.67	+0.57
30	−0.08	+0.03	+0.67	+0.54
Oct. 16	−0.34	−0.34	−0.26	−0.36
26	+0.08	+0.02	−0.38	−0.41
Nov. 13	+0.89	+1.04	+0.64	+0.75
25	−1.63	−1.31	−2.02	−1.81

8. The extent, homogeneity and excellence of the Lick series of observations, by **Barnard**, entitle it to distinct and separate treatment, for the reasons and purpose set forth in section 3. I have therefore made an independent solution by the same methods as for the general one. Suppressing the details, it will suffice to give the resulting elements, and their comparison with the individual observed position-angles and distances. The elements thus derived, employing only the observations with the 36-inch, are

$$\left.\begin{aligned} \Delta T &= -0^{\text{d}}.2170 \\ \Delta\omega &= -162''.4 \\ \Delta q &= -0.000454 \end{aligned}\right\}\ \text{III}$$

The corresponding corrections to the ephemeris in section 5 have already been given in the beginning of section 6. Converting into distance and position-angle, we find the following residuals (C—O).

	″	°
Aug. 3	+0.66	+0.32
4	−0.38	+0.21
5	−0.46	+0.30
16	+0.37	+0.15
17	+0.03	−0.25
18	−0.40	−0.05
19	−0.39	−0.15
20	+0.01	−0.45
21	−0.60	+0.65
22	−0.10	−0.15
23	−0.11	−0.15
24	−1.52	+0.15
25	−0.59	−0.05
26	+0.72	+0.36
27	+0.56	+0.26
28	+1.19	+0.06
29	+0.60	+0.16
31	−0.24	+0.26
Sept. 2	+0.52	+0.37
3	−0.76	−0.03
4	−0.14	−0.01
Sept. 4	+1.32	−0.24
5	−0.34	−0.24
5	−0.93	−0.14
12	–	−0.16
14	−1.04	−0.28
15	−1.37	−0.49
16	+0.38	−0.10
17	+0.81	−0.01
18	+0.41	−0.11
19	−1.33	−0.03
19	+0.38	−0.03
20	−0.47	+0.06
21	+0.69	+0.35
22	+0.42	+0.13
23	+1.76	−0.09
24	0.00	+0.19
25	+0.04	+0.17
26	−0.20	+0.25
27	−0.59	+0.03
28	+0.27	0.00
29	+0.76	+0.08
Sept. 30	−0.24	−0.04
Oct. 1*	+0.16	+0.13
2	−0.57	–
3	−0.10	–
4	−0.66	+0.11
10	−1.01	−0.27
11	−0.79	+0.09
14	−0.18	+0.21
15	+0.26	−0.08
23	+0.37	+0.16
24	−0.33	−0.29
28	−0.11	+0.33
30	+0.50	−0.06
Nov. 10	−0.70	+0.07
11	−0.78	+0.14
13	−1.31	+0.17
16	–	−0.16
24	+3.62	−0.11
25	−1.28	−0.76

The probable errors of a single observation, ±0″.613 and ±0°.175, although, for obvious reasons, considerably larger than those given by **Barnard**, are nevertheless highly satisfactory, and emphasize the advantageous conditions enjoyed at that observatory. The persistence of the same sign in the residuals during series of nights together, especially noticeable in the position-angles, may be attributed to some form of unconscious and unavoidable bias of the observer, or possibly to apparent changes in the physical appearance of the comet or its companion.

Deferring for the present the general consideration of the results given in this paper, the orbits of the other companions will receive attention in an early number.

Cambridge, Mass., 1891 *Feb.* 2.

OBSERVED MAXIMUM OF *U GEMINORUM.*

By PAUL S. YENDELL.

This variable has recently passed a bright maximum. It was not seen when looked for 1891 Jan. 3, when stars of 11.0 mag. were well seen; at the next observation, Jan. 8, the star was near its maximum, being equal to Knott's comparison-star *C*, whose magnitude according to Baxendell is $9^{M}.2$; from this date to January 16, eight observations were obtained, indicating maximum about Jan. 9.7, local M.T., at a magnitude estimated at 8.9.

The individual observations are as follows, the magnitudes being carefully estimated from Baxendell's.

1891 Jan.	8.333 Local M.T.	9.2 mag.
	9.333	8.9*
	10.302	8.9
	12.354	8.95
	13.434	9.2
	14.407	9.1
	15.323	9.25†
	16.340	9.5†

A three-days' storm, beginning on the 17th, prevented the further following of the star's variations.

* Hazy. † Moon present, but its light does not seem to have affected the estimates.

Dorchester, Mass., 1891 *Jan.* 24.

EPHEMERIS OF COMET *f* 1890,

(Continued from page 143).

By GEORGE E. WHITAKER.

1891	App. α	App. δ	log *r*	log Δ	Br.
	h m s	° ′			
Feb. 12.5	5 13 24	+39 40.7			
14.5	15 53	39 35,9	0.3186	0.1687	0.30
16.5	18 29	39 31.0			
18.5	21 11	39 26.0			
20.5	23 57	39 20.8			
22.5	26 49	39 15.4	0.3253	0.1992	0.26
24.5	29 16	39 9.9			
26.5	32 48	39 4.2			
28.5	35 54	38 58.3			
Mar. 2.5	39 4	38 52.2	0.3321	0.2289	0.22
4.5	42 18	38 45.9			
6.5	45 36	38 39.5			
8.5	48 58	38 32.9			
10.5	52 23	38 26.1	0.3391	0.2577	0.18
12.5	55 51	38 19.1			
14.5	5 59 22	+38 11.9			
Mar. 16.5	6 2 56	+38 4.5			
18.5	6 32	37 56.8	0.3461	0.2855	0.15
20.5	10 10	37 49.0			
22.5	13 50	37 40.9			
24.5	17 32	37 32.6			
26.5	21 16	37 24.0	0.3532	0.3121	0.13
28.5	25 1	37 15.2			
30.5	28 48	37 6.2			
Apr. 1.5	32 36	36 56.9			
3.5	36 25	36 47.4	0.3604	0.3375	0.11
5.5	40 15	36 37.6			
7.5	44 6	36 27.6			
9.5	47 58	36 17.3			
11.5	51 50	36 6.7	0.3675	0.3618	0.10
13.5	55 43	35 55.9			
15.5	6 59 36	+35 44.8	0.3711	0.3734	0.09

Cambridge, Mass., 1891 *Feb.* 2.

CORRIGENDUM.

No. 233, p. 130, col. 2. line 6 from below, in 2d term, *for* $\frac{1}{2}R$ *put* $\frac{1}{2}R^2$.

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Corrigendum.

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DEFINITIVE ORBITS OF THE COMPANIONS OF COMET 1889 V.

BY S. C. CHANDLER.

II.

9. The measurements of companion *B* comprise only 23 at Lick, and 6 at Vienna, and cover an interval of but 35 days. The second and third columns below contain the data as given by the observer in the second and third columns, which I have referred to the plane of the orbit of *A*, in the fourth and fifth columns.

Gr. M.T.	s	p	$\cos\eta\,\Delta\theta$	$\Delta\eta$	Authority
	″	°	″	″	
Aug. 1.925	64.8	59.4	+64.8	+1.6	L : B (12)
2.942	(65.7)	(64.0)	(66.9)	(−3.8)	"
3.873	66.5	59.9	66.5	+1.0	L : B (36)
4.921	68.5	60.5	68.5	+0.3	"
5.852	67.9	59.9	67.9	+1.0	"
16.891	72.4	61.3	72.4	−0.8	"
17.894	73.8	61.7	73.8	−1.4	"
18.873	73.4	61.2	73.4	−0.7	"
19.866	73.9	61.3	73.9	−0.9	"
20.873	73.4	61.5	73.4	−1.1	"
21.894	73.7	61.0	73.7	−0.5	"
22.894	73.5	61.6	73.5	−1.2	"
23.888	73.7	61.3	73.7	−0.9	"
24.822	74.1	60.5	74.1	+0.2	"
25.818	74.3	61.4	74.3	−1.0	"
26.867	72.3	61.3	72.3	−0.8	"
27.825	74.6	62.7	74.5	−2.7	"
28.849	73.2	63.2	73.1	−3.2	"
29.906	73.2	63.2	73.1	−3.4	"
31.881	72.6	62.0	72.6	−1.7	"
Sept. 2.846	71.1	63.9	71.0	−3.9	"
4.881	71.6	65.0	71.4	−5.2	"
5.936	(62.6)	(62.5)	+(62.6)	(−2.0)	"

	$\Delta\alpha$	$\Delta\delta$	$\cos\eta\,\Delta\theta$	$\Delta\eta$	
	s	″	″	″	
Aug. 4.552	+3.38	+ 9.1	+48.3	−16.9	V : S
5.552	4.15	16.1	61.8	−16.3	"
7.552	4.50	24.8	70.8	−11.3	"
19.553	4.40	30.6	72.2	− 9.5	V : P
24.430	4.16	33.2	79.4	− 1,5	"
28.437	+4.73	+34.0	+78.2	− 1.9	"

The Lick observations of Aug. 2 and Sept. 5 are indicated for rejection by the observer.

I am unable to see any palpable basis for BARNARD's remark that "the sudden change in the position-angle of *B* about Aug. 26 is real, and seems to have been intimately connected with the rapid disintegration this companion underwent in the next ten days, and which culminated in its total dissolution about Sept. 5." The change in question is scarcely greater than the uncertainty of observation.

10. In attempting to find the most probable orbit of *B* from a discussion of the above material, we meet two obstacles to a satisfactory solution. The first arises from the serious discordances between the Vienna and the Lick observations, already noticed in a less degree in those of companion *C* (p. 157); and the second from the fact that the period of observation was too short to furnish relations in the equations of condition, sufficiently independent for determinate values of all the unknown quantities. After expending much time and labor in futile experiment with various hypotheses, I am forced to the conclusion that the only way to meet the first difficulty — since the Vienna observations are not numerous enough to be independently discussed — is to assume the correctness and homogeneity of the Lick series, with the 36-inch, and to base the calculation on them alone. As to the second difficulty, all that we can do is to find what conic section is most compatible with the observations, after introducing analogical assumptions suggested by the discussion of companion *C*.

11. From the observations with the 36-inch we form the following normal differences in θ and η.

Date	n	$\cos\eta\,\Delta\theta$	$\Delta\eta$
		″	″
Aug. 5.0	3	+67.67	+0.78
19.0	7	73.36	−0.85
28.0	8	73.42	−1.80
Sept. 3.0	2	+71.43	−4.23

Substituting these in the second members of the first four equations in longitude, and the first four in latitude, on p. 158, with the appropriate weights, we derive the normal equations.

$$\begin{array}{rrrrrrcr}
+67.785x & -139.473y & +137.978t & -0.599u & -0.440w & -106.770z & = & +2662.64\\
-139.473 & +301.046 & -290.315 & -0.278 & -0.206 & +219.362 & = & -5526.19\\
+137.978 & -290.315 & +331.655 & -27.329 & -19.153 & -216.334 & = & +5364.75\\
-0.599 & -0.278 & -27.329 & +15.372 & +10.537 & +0.572 & = & +24.558\\
-0.440 & -0.206 & -19.153 & +10.537 & +7.527 & +0.421 & = & +14.042\\
-106.770 & +219.362 & -216.334 & +0.572 & +0.421 & +167.938 & = & -1188.76
\end{array}$$

The indeterminateness of the solution is apparent from the smallness of the coefficients of the last three elimination-equations; thus,

$$\begin{array}{rrrcr}
+0.2185u & -0.0860w & +0.0077z & = & +1.256\\
 & +0.0462 & -0.0021 & = & -1.213\\
 & & 0.0000 & = & -0.025
\end{array}$$

whence it is manifest that the endeavor to reach any result, without importing extraneous conditions, would be merely playing with figures. However, it may be worth while to give the results of the solution, disregarding z:

$$\begin{array}{rcrr}
x & = & +41.288 & +1.58268z\\
y & = & -13.097 & -0.00074\\
t & = & -14.359 & -0.00553\\
u & = & -4.576 & -0.01704\\
w & = & -26.233 & +0.04624
\end{array}$$

which give, introducing the homogeneity-factors on p. 158,

$$\text{I}\left\{\begin{array}{rcrl}
\Delta\chi' & = & +41''.29 & +1582.68\ dT\\
\Delta e & = & -0.001310 & -0.000074\ dT\\
\Delta T & = & 0^d.0000 & \\
\Delta q & = & -0.001436 & -0.000553\ dT\\
\Delta\Omega' & = & -4''.58 & -17.04\ \ dT\\
\Delta i' & = & -26''.23 & +46.24\ \ dT
\end{array}\right.$$

The corresponding values of the coordinates for the normal dates will be found in section 12, headed I.

In the case of companion C, where the observations were competent to establish the point with certainty, it was found that the plane and form of the conic section were identical with those of A. To see how nearly a similar condition as to the orbital plane will conform to the observations of B, let us put u and $w = 0$ in the above normal equations. We then find,

$$\text{II}\left\{\begin{array}{rcrl}
\Delta\omega = \Delta\chi' & = & +32''.95 & +1588.03\ \ dT\\
\Delta e & = & -0.000456 & -0.0006551\ dT\\
\Delta q & = & -0.000153 & -0.0014113\ dT
\end{array}\right.$$

Substituting these in the equations of condition we get $z = +13.5$, but the corresponding changes in the elements II are so slight that we can disregard them, and adopt the above values, with $\Delta T = 0.000$, as the result of the hypothesis of identical planes. The corresponding coordinates II are given in section 12.

To test the hypothesis of identity of form and plane of the orbit of B with those of A, put $dT = -0^d.697$ in elements II; obtaining thus:

$$\text{III}\left\{\begin{array}{rcl}
\Delta T & = & -0^d.697\\
\Delta\omega = \Delta\chi' & = & -1074''.0\\
\Delta q & = & +0.000831\\
\Delta e & = & 0.000000
\end{array}\right.$$

the coordinates for which are given under III below.

12. The comparison of the foregoing results with the observations may be made by means of the following table.

	Lick	Vienna	I	II	III	
	″	″	″	″	″	
Aug. 5	+67.67	+59.6	+67.59	+69.11	+68.40	$\cos\delta\,\Delta\alpha$
19	73.36	72.2	73.52	72.38	72.27	
28	73.42	78.2	73.11	73.34	73.11	
Sept. 3	+71.43	–	+71.69	+73.19	+73.26	
Aug. 5	+0.78	−14.8	+1.56	−0.68	−6.95	$\Delta\delta$
19	−0.85	−9.5	−1.13	−1.24	−2.26	
28	−1.80	−1.9	−1.75	−1.46	+0.90	
Sept. 3	−1.23	–	−2.58	−1.55	+2.66	

The close accordance of I with the Lick observations is not evidence of the superior correctness of that system of elements, but is a mere computation-result, the adjustment of five unknowns to eight equations. The values II allow us to infer that the hypothesis of identity in the planes of B and A is consistent with the observations, within the range of the uncertainty of the latter. As to III, taking into account the divergence between the Lick and Vienna positions, we can at least say that the hypothesis of identity in the form of the orbits of B and A is not manifestly contradicted by the data. This seems to be as far as legitimate inference can go in the case of this companion, and to this extent the results may be regarded as entirely harmonious with those established for the companion C (section 7). But we are obliged to conclude that the absolute elements of B are indeterminate from the 1889 observations. Doubtless the apparition of 1896, if B should then be visible, will solve the problem.

One remark in addition. The companion B was seen, but not measured, by SPITALER on Oct. 23, seven weeks after BARNARD's last observation. This, the latter says, he is at a loss to understand, as B was certainly not visible on that date with the 36-inch. But neither this, nor the fact that SPITALER could not see it on the following day, appears to be good reason to distrust the observation; for, first, BARNARD's own note on Oct. 23 shows that the conditions of seeing were unfavorable; and, secondly, the considerations advanced in section 1 should make us cautious in too hastily discrediting the perception of a trustworthy observer on merely negative evidence.

13. The companions D and E were measured at Lick on Aug. 4 only. At Vienna E was measured on Aug. 5 and Oct. 23. The elements of the latter have been assigned by BREDICHIN from these data (*A.N.* CXXIII, 321), and nothing can be added here.

In conclusion, the only one of the four companions whose elements can be regarded as fixed with enough precision to enable us to found further calculations thereupon, — either of prediction for its subsequent return to perihelion, or of investigation as to the origin of its separation from the principal component, — appears to be the fragment C. In this case, however, the orbit is so sharply defined that we may reasonably anticipate satisfactory enlightenment from a mathematical examination of this interesting problem, which is reserved for presentation in a subsequent paper.

Cambridge, Mass., 1891 *Feb.* 11.

ON THE CORRECTION OF PHOTOGRAPHIC MEASURES FOR REFRACTION.

By HAROLD JACOBY.

The refraction-correction of photographic measures of distance and position-angle is easily computed by means of **Bessel**'s formulas, which express the correction in terms of the position-angle, and of certain quantities which are functions of the declination and hour-angle. These latter quantities are the zenith-distance and parallactic-angle. In computing them it is necessary to use the means of the declinations and hour-angles belonging to the two stars.

But if a large number of corrections have to be computed for pairs of stars on a single photographic plate, it will be found convenient to use the declination, hour-angle, zenith-distance and parallactic angle of the center of the plate; and, when necessary, we may then apply a small correction, obtained by differential formulas, to make up for the resulting error. Introducing **Bessel**'s notation, let us put:

ζ, q, A''	the true zenith-distance, parallactic angle and azimuth corresponding to the center of the plate.
δ, t,	the true declination and hour-angle for the same point.
σ, s	the true and apparent distances of the stars.
π, p	the true and apparent position-angles of the line joining the stars (a).

Now, since we may write:

$$\frac{\sigma - s}{s} = f(\zeta, q, p), \quad \zeta = \phi(\delta, t), \quad q = \psi(\delta, t)$$

we shall have:

$$\Delta\left(\frac{\sigma - s}{s}\right) = \frac{df}{d\zeta}(\zeta' - \zeta) + \frac{df}{dq}(q' - q) + \ldots$$

and since:

$$\zeta' - \zeta = \frac{d\phi}{dt}(t' - t) + \frac{d\phi}{d\delta}(\delta' - \delta) + \ldots .$$

$$q' - q = \frac{d\psi}{dt}(t' - t) + \frac{d\psi}{d\delta}(\delta' - \delta) + \ldots .$$

we get:

$$(1) \qquad \Delta\left(\frac{\sigma - s}{s}\right) = \left(\frac{df}{d\zeta}\cdot\frac{d\phi}{dt} + \frac{df}{dq}\cdot\frac{d\psi}{dt}\right)(t' - t) + \left(\frac{df}{d\zeta}\cdot\frac{d\phi}{d\delta} + \frac{df}{dq}\cdot\frac{d\psi}{d\delta}\right)(\delta' - \delta) + \ldots$$

and the terms containing the squares and products of $(t' - t)$ and $(\delta' - \delta)$ will be found inappreciable. The quantity

$$\Delta\left(\frac{\sigma - s}{s}\right)$$

is a correction which must be added to the value of

$$\frac{\sigma - s}{s}$$

computed with the δ and t of the center of the plate; and if δ_0 and t_0 be the mean declination and hour-angle of the two stars, we must substitute in the above formulas:

$$\delta' - \delta = \delta_0 - \delta, \qquad t' - t = t_0 - t$$

Now, the Besselian expression for the refraction in distance is:

$$\frac{\sigma - s}{s} = \kappa\left[\tan^2\zeta\cos^2(p - q) + 1\right]$$

in which κ is practically constant for the whole plate, if the zenith distance does not exceed 60°; so that we have:

$$\frac{df}{d\zeta} = 2\kappa\cos^2(p - q)\tan\zeta\sec^2\zeta \qquad \frac{df}{dq} = \kappa\tan^2\zeta\sin 2(p - q)$$

$$\frac{d\phi}{dt} = \cos\delta\sin q \qquad \frac{d\psi}{dt} = \frac{\cos A''\cos\varphi}{\sin\zeta}$$

$$\frac{d\phi}{d\delta} = -\cos q \qquad \frac{d\psi}{d\delta} = \sin q\cot\zeta$$

If then we put:

$a = 2\kappa\sin 1''\tan\zeta\sec^2\zeta\cos\delta\sin q$ $\qquad A = \cos^2(p - q)$

$b = \kappa\sin 1''\tan\zeta\sec\zeta\cos A''\cos\delta$ $\qquad B = \sin 2(p - q)$

$c = -2\kappa\sin 1''\tan\zeta\sec^2\zeta\cos q$

$d = \kappa\sin 1''\tan\zeta\sin q$

equation (1) becomes:

$$\Delta\left(\frac{\sigma - s}{s}\right) = (aA + bB)(t_0 - t) + (cA + dB)(\delta_0 - \delta)$$

and the final formula for the correct refraction in distance is

$$\sigma - s = s\kappa\left[\tan^2\zeta\cos^2(p - q) + 1\right] + s(aA + bB)(t_0 - t) + s(cA + dB)(\delta_0 - \delta),$$

$t_0 - t$ and $\delta_0 - \delta$ being expressed in seconds of arc.

If many stars on the same plate are to be reduced it will be convenient to tabulate the three quantities.

$$\kappa\left[\tan^2\zeta\cos^2(p - q) + 1\right]$$
$$(aA + bB)$$
$$(cA + dB)$$

with the argument p, since for any particular plate, p is the only variable entering into these quantities. This tabulation will be extremely easy, since a, b, c, d are all constants for

---

(a) It should be observed that p is here the position-angle at the middle point of the line in question. But it will be sufficiently accurate to employ the mean of the values of the position-angle at the two ends of the line, and this will generally be more convenient.

the plate, and easily calculated with the help of a parallactic table, and the variables A and B are expressions of a very simple form.

For position-angles we proceed in a similar way; but now equation (1) will take the slightly less simple form:

$$\Delta(\pi-p)=\left(\frac{df}{d\zeta}\cdot\frac{d\phi}{dt}+\frac{df}{dq}\cdot\frac{d\psi}{dt}\right)(t'-t) \qquad (2)$$
$$+\left(\frac{df}{d\zeta}\cdot\frac{d\phi}{d\delta}+\frac{df}{dq}\cdot\frac{d\psi}{d\delta}+\frac{df}{d\delta}\right)(\delta'-\delta)+\ldots$$

And further, the Besselian equation being

$$\pi-p=-\kappa\operatorname{cosec}1''[\tan^2\zeta\cos(p-q)\sin(p-q)$$
$$+\tan\zeta\sin q\tan\delta]$$

we obtain:

$$\frac{df}{d\zeta}=-\kappa\operatorname{cosec}1''[\tan\zeta\sec^2\zeta\sin 2(p-q)+\sin q\tan\delta\sec^2\zeta]$$
$$\frac{df}{dq}=-\kappa\operatorname{cosec}1''[-\tan^2\zeta\cos 2(p-q)\quad+\tan\zeta\tan\delta\cos q]$$
$$\frac{df}{d\delta}=-\kappa\operatorname{cosec}1''\tan\zeta\sin q\sec^2\delta$$

We have then, as before, putting:

$a'=-\kappa\tan\zeta\sec^2\zeta\cos\delta\sin q \qquad A'=\sin 2(p-q)$
$b'=-\kappa\sec^2\zeta\sin\delta\sin^2 q \qquad B'=\cos 2(p-q)$
$c'=+\kappa\tan\zeta\sec\zeta\cos\phi\cos A''$
$d'=-\kappa\sec\zeta\tan\delta\cos q\cos A''\cos\phi$
$e'=+\kappa\tan\zeta\sec^2\zeta\cos q$
$f'=+\kappa\sec^2\zeta\tan\delta\sin q\cos q$
$g'=+\kappa\tan\zeta\sin q$
$h'=-\kappa\tan\delta\sin q\cos q$
$i'=-\kappa\tan\zeta\sin q\sec^2\delta$

$$\Delta(\pi-p)=(a'A'+b'+c'B'+d')(t_0-t)$$
$$+(e'A'+f'+g'B'+h'+i')(\delta_0-\delta)$$

and the final formula for position-angles is:

$$\pi-p=-\kappa\operatorname{cosec}1''[\tan^2\zeta\cos(p-q)\sin(p-q)$$
$$+\tan\zeta\sin q\tan\delta]$$
$$+(a'A'+b'+c'B'+d')(t_0-t)$$
$$+(e'A'+f'+g'B'+h'+i')(\delta_0-\delta)$$

while the tabulation of the quantities

$$\tan^2\zeta\cos(p-q)\sin(p-q)+\tan\zeta\sin q\tan\delta$$
$$a'A'+b'+c'B'+d'$$
$$e'A'+f'+g'B'+h'+i'$$

with the argument p, can be carried out as easily as before.

The above formulas take a different form, if one end of the line for which the refraction is being computed is at the center of the plate (b).

We shall then have:

$$\delta'-\delta=\tfrac{1}{2}s\cos p$$
$$t'-t=-\tfrac{1}{2}s\sin p\sec\delta$$

by means of which we can transform (1) and (2) as follows:

For refraction in distance, putting

$a=-\kappa\sin 1''\sin q\tan\zeta\sec^2\zeta \qquad A=\sin p\cos^2(p-q)$
$b=-\tfrac{1}{2}\kappa\sin 1''\sec\zeta\tan\zeta\cos\phi\cos A''\sec\delta$
$\qquad B=\sin p\sin 2(p-q)$
$c=-\kappa\sin 1''\tan\zeta\sec^2\zeta\cos q \qquad C=\cos p\cos^2(p-q)$
$d=\tfrac{1}{2}\kappa\sin 1''\tan\zeta\sin q \qquad D=\cos p\sin 2(p-q)$

we have

$$\sigma-s=s\kappa[\tan^2\zeta\cos^2(p-q)+1]+s^2[aA+bB+cC+dD];$$

and for position-angles, putting:

$a'=\tfrac{1}{2}\kappa\tan\zeta\sec^2\zeta\sin q \qquad A'=\sin 2(p-q)\sin p$
$b'=\tfrac{1}{2}\kappa\sec^2\zeta\sin^2 q\tan\delta \qquad B'=\sin p$
$c'=-\tfrac{1}{2}\kappa\tan\zeta\sec\zeta\cos\phi\cos A''\sec\delta$
$\qquad C'=\cos 2(p-q)\sin p$
$d'=\tfrac{1}{2}\kappa\sec\zeta\tan\delta\sec\delta\cos q\cos A''\cos\phi$
$e'=\tfrac{1}{2}\kappa\tan\zeta\sec^2\zeta\cos q \qquad E'=\sin 2(p-q)\cos p$
$f'=\tfrac{1}{2}\kappa\sec^2\zeta\sin q\cos q\tan\delta \qquad F'=\cos p$
$g'=\tfrac{1}{2}\kappa\sin q\tan\zeta \qquad G'=\cos 2(p-q)\cos p$
$h'=-\tfrac{1}{2}\kappa\tan\delta\sin q\cos q$
$i'=-\tfrac{1}{2}\kappa\tan\zeta\sin q\sec^2\delta$

we get:

$$\pi-p=-\kappa\operatorname{cosec}1''[\tan^2\zeta\cos(p-q)\sin(p-q)$$
$$+\tan\zeta\sin q\tan\delta]$$
$$+s[a'A'+b'B'+c'C'+d'B'+e'E'+f'F'+g'G'+h'F'+i'F'$$

In using the formula for refraction in distance, we might tabulate the coefficients of s and s^2, with the argument p, and form such a table for each plate to be reduced; and for the position-angles we would tabulate the first term, and the coefficient of s. Although the formulas appear somewhat complicated, the formation of such tables would be quite easy, especially as nearly all the terms in the coefficient of s^2 for distances and s for position-angles would be inappreciable in most cases. For instance, the zenith distance at which the term in s^2 can, at its maximum, amount to 0''.01, the declination being supposed as great as 60°, is:

for $s = 2000''$ $\qquad \zeta = 42°$
$s = 2500$ $\qquad \zeta = 33°$

while for position-angles the maximum value of the term in s cannot exceed 5''.

for $s = 2000''$ $\qquad$ when $\zeta = 35°$
$s = 2500$ $\qquad \zeta = 24°$

But this does not by any means indicate that the quantities in question will often be so large at the zenith distances mentioned.

Lastly, it should be again observed that the final formulas just given are adapted for the correction of distances measured from the center of the plate in accordance with the method of reduction for photographic plates given in *Astronomical Journal*, no. 233. The distances will therefore *rarely* exceed 2500'', so that it will frequently happen that the differential corrections will turn out quite negligible either for the distances, or position-angles, or for both.

Columbia College, New York, 1891 *January* 27.

(b) This will be the case if the positions of the various stars on the plate have been determined with a machine giving position-angles and distances from a central star; or in any case where the method of reduction, given in *Astronomical Journal*, No. 233, has been employed.

SUN-SPOT OBSERVATIONS,

MADE AT BRYN MAWR, PENN., WITH A 3 INCH REFRACTOR

BY A. W. QUIMBY.

1890	Time	Grs.	Sps.	Fac. Grs.	Def.
July 1	6	0	0	0	good
2	10	0	0	0	poor
3	7	0	0	0	"
4	7	0	0	0	"
5	9	1	25	1	fair
6	7	1	32	1	good
7	7	1	11	1	"
8	7	1	39	1	"
9	7	1	42	0	"
10	7	1	49	0	"
11	7	1	29	0	fair
12	7	1	12	0	poor
14	8	1	4	1	"
15	7	0	0	2	fair
16	7	0	0	1	"
17	7	0	0	0	"
18	7	0	0	0	"
19	7	0	0	0	"
20	7	0	0	0	poor
21	7	0	0	0	fair
22	7	1	4	0	"
23	7	1	9	1	good
24	2	0	0	0	bad
25	6	1	2	0	poor
26	2	1	25	0	fair
27	8	1	10	0	poor
28	8	2	6	0	"
29	3	2	3	1	"
30	7	3	14	1	good
31	7	3	5	1	"
Aug. 1	7	3	4	1	good
2	7	2	3	1	"
3	7	1	2	0	poor
4	7	1	6	0	fair
5	6	1	10	0	good
6	7	1	4	0	poor
7	7	2	12	0	fair
8	12	0	0	0	bad
9	10	0	0	0	"
10	6	0	0	0	good
11	6	1	1	1	"
12	6	0	0	0	fair
13	9	0	0	0	poor
14	6	0	0	0	"
15	6	0	0	0	fair
16	6	0	0	0	good
17	7	0	0	0	fair
18	2	0	0	0	bad
19	12	0	0	0	"
20	12	0	0	0	"
21	7	0	0	0	"
22	7	0	0	0	fair
23	7	0	0	0	good
24	7	0	0	0	fair
25	7	1	1	1	good
26	12	1	4	0	poor
Aug. 27	7	1	14	1	poor
28	7	1	100	0	good
29	7	1	76	0	"
30	7	1	67	0	"
31	7	1	96	0	"
Sept. 1	7	2	60	0	fair
2	7	2	45	0	"
3	7	2	56	0	good
4	7	2	31	0	"
5	7	2	11	0	"
6	7	3	21	2	fair
7	7	1	21	3	good
8	7	3	20	3	"
9	7	2	18	1	fair
10	7	1	10	0	poor
12	9	0	0	0	bad
13	10	0	0	0	"
15	4	1	3	2	fair
16	11	1	2	0	poor
17	2	2	14	0	fair
18	7	2	43	0	"
19	7	2	26	0	"
20	8	1	7	0	poor
21	8	1	. .	1	"
22	11	0	0	0	"
23	8	0	0	2	fair
24	8	1	17	0	"
25	8	1	29	0	"
28	8	1	12	0	poor
29	7	1	7	0	"
30	8	1	17	1	fair
Oct. 1	8	1	9	1	good
3	10	0	0	1	fair
4	8	1	1	3	good
5	8	1	5	2	"
8	8	0	0	0	fair
9	7	0	0	0	good
10	10	0	0	0	fair
11	9	1	4	3	good
12	9	1	5	1	"
13	8	0	0	0	poor
14	3	0	0	0	fair
15	8	0	0	1	"
16	8	0	0	0	poor
17	9	0	0	0	fair
18	8	0	0	1	"
19	8	1	3	1	poor
20	12	1	15	3	fair
21	1	2	59	2	"
22	8	2	15	0	"
25	8	1	55	0	"
26	8	1	27	0	poor
27	8	1	. .	0	bad
28	1	1	16	0	poor
29	2	1	19	0	"
Oct. 30	8	1	9	0	fair
31	8	1	6	0	"
Nov. 1	8	0	0	0	fair
2	8	0	0	0	"
3	8	0	0	0	"
4	8	0	0	0	poor
5	8	0	0	0	fair
6	1	0	0	0	poor
7	9	0	0	0	"
8	8	1	7	1	fair
9	8	1	10	1	"
10	8	1	7	0	poor
13	8	1	5	0	"
14	8	1	4	0	"
15	8	0	0	1	"
16	8	0	0	1	"
18	8	0	0	2	fair
19	8	0	0	0	"
20	8	0	0	0	poor
21	8	0	0	0	fair
22	9	1	5	1	poor
23	9	1	26	1	fair
24	9	1	39	1	"
25	9	1	50	0	"
26	1	1	40	0	"
27	9	1	46	2	good
28	9	1	26	2	"
29	9	1	55	0	"
30	1	1	26	0	fair
Dec. 1	9	0	0	0	fair
2	8	0	0	0	"
4	9	0	0	0	"
5	11	0	0	0	"
7	9	0	0	0	poor
9	9	0	0	0	"
10	9	0	0	0	"
11	9	0	0	0	fair
12	4	0	0	0	poor
13	10	2	20	1	fair
14	9	2	18	0	poor
15	10	2	15	0	fair
18	9	2	30	0	poor
19	9	2	27	0	"
20	9	2	15	0	fair
21	3	0	0	0	poor
22	8	0	0	0	"
23	8	0	0	0	"
24	8	0	0	2	fair
25	8	0	0	0	poor
27	10	0	0	0	"
28	3	1	5	1	fair
29	9	1	7	1	"
30	9	1	7	2	"
31	12	1	6	2	"

FILAR-MICROMETER OBSERVATIONS OF COMET *e* 1890 ZONA.

MADE WITH THE 26-INCH EQUATORIAL OF THE LEANDER McCORMICK OBSERVATORY OF THE UNIVERSITY OF VIRGINIA.

(Communicated by the Director.)

1890-91 local M.T.	✱	No. Comp.	☌′ — ✱ $\Delta\alpha$	☌′ — ✱ $\Delta\delta$	☌′'s apparent α	☌′'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ	Obs.
			m s	″	h m s	° ′ ″			
Nov. 18 14 1 54	1	4 , 4	+3 8.10	+0 31.9	5 16 45.40	+34 9 50.0	8.978	9.800	P
16 3 4	1	3 , 4	+2 39.21	+1 32.0	5 16 16.54	+34 10 51.0	9.465	0.065	S
19 13 51 1	2	0 , 4	. . . . . .	+3 8.4	. . . . . .	+34 21 18.9	8.990	9.771	P
Dec. 10 8 11 6	3	1 , 2	+0 38.77	+0 0.0	. . . . . .	. . . . . .	n9.100	9.813	D
9 3 26	4	2 , 2	—2 56.19	+2 46.0	3 14 46.01	+33 56 56.9	n9.236	9.894	D
Jan. 5 9 48 27	5	6 , 2	+1 20.83	—1 15.3	1 56 1.06	+28 41 26.1	9.562	0.366	S
9 48 27	6	6 , 4	—0 30.56	+0 53.9	1 56 4.19	+28 41 29.9*	9.562	0.366	S
7 10 3 8	7	11 , 6	+0 10.12	+1 47.9	1 52 49.28	+28 21 51.7	9.874	n0.134	S

* Micrometer-readings changed in reduction by five revolutions. = +49″.4.

Mean Places for 1890.0 and 1891.0 of Comparison-Stars.

✱	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	5 13 33.62	+3.68	+34 9 14.6	+ 4.4	Paris, 6107
2	5 8 10.33	+3.64	+34 18 10.5	+ 4.7	W.B., 151,2
3	3 11 5	+3.61	+33 56	+16.7	DM., 626
4	3 17 38.89	+3.61	+33 53 54.5	+16.4	Paris, 4019
5	1 54 13.96	—0.73	+28 42 38.1	+ 3.3	Paris, 2496
6	1 56 35.47	—0.72	+28 39 43.3	+ 3.3	Paris, 2547
7	1 52 39.91	—0.75	+28 20 0.6	+ 3.2	Paris, 2444

S = ORMOND STONE; P = N. M. PARRISH; D = C. L. DEMOTT.

Nov. 18. P. telescope badly shaken by the wind.

Nov. 18. S. at first obs. of decl., position coincided with that of a very faint star, which however was not occultated.

Nov. 19. Diameter 0′.8; nucleus 11.5 mag.

Dec. 10. Nucleus pretty bright.

Jan. 5. Diameter 1′; faint; diffuse; nucleus 15 mag.

Jan. 7. Very faint; small.

ON THE ORBIT OF COMET 1887 IV.

BY S. C. CHANDLER.

Nearly two years and a half ago, Mr. MULLER published (*A.J.*, VIII, 44–56) a thorough discussion of the definitive orbit of this comet. In *A.N.* 3012, 3013, is an article on the same subject by Mr. ABETTI, containing various comments on that of Mr. MULLER, and concluding with a comparison of the latter's elements with his own normal places. The natural impression which this leaves on the mind, unfavorable to the character of MULLER's work, is so far from being justified that, in the interests of astronomical truth, and fairness to Mr. MULLER, who is now in Japan, and not in a position to reply, the real sources of the discordances need to be pointed out. An examination shows that these lie entirely in grave errors and defective methods of Mr. ABETTI's own work, and confirms the high character of that of Mr. MULLER. In what follows I shall endeavor to make a moderate and just, although frank, statement of the reasons for this opinion. If they should prove not to be sound, I shall be glad to make due apology.

First, we look in vain through his copious explanations for an investigation of the perturbations, by Mr. ABETTI, who seems to overlook the fact that his elements are adjusted merely to satisfy the disturbed coordinates, and that Mr. MULLER's elements, which were freed from the perturbations of all the planets from *Mercury* to *Saturn*, cannot properly be confronted with the uncorrected normals. The disturbances by the *Earth* and *Jupiter* ought at least to have been considered. This defect alone is enough to invalidate Mr. ABETTI's orbit, as is manifest by the following table where, by the side of his values of the deviations of his normals, I have placed the values approximately corrected for the perturbations, — the osculation-epoch being June 27.

1887	O—C uncorrected $\Delta\alpha\cos\delta$	O—C uncorrected $\Delta\delta$	O—C corrected $\Delta\alpha\cos\delta$	O—C corrected $\Delta\delta$
	″	″	″	″
May 22.5	—0.62	+1.20	+3.34	—0.07
June 17.5	—0.15	—1.37	+0.23	—1.31
July 11.5	+0.97	+0.70	+1.70	+0.91
July 27.5	—0.13	+1.19	+2.76	+2.02

Secondly, the normal places appear to be incorrectly derived, nearly all the coordinates requiring more or less rectification. A casual inspection of the data on pp. 203, 204, will suffice to show that the provisory orbit is not precise enough to allow the assumption that the residuals bear a linear relation to the time, over the interval of three weeks embraced in the determination of each normal. This is notably the case, for example, in the second normal in declination. On this point examine the character of the differences in the table of the foot-note to p. 183, A. N.: recollecting that Muller's preliminary orbit, used by him for comparison with the observations, differs from them nowhere by so much as 10″. It is probable that, if the final elements were compared directly with the separate observations, and the normals computed anew, decidedly important corrections would result.

Thirdly, no investigation was made of constant errors, a point which was treated by Muller with much refinement. This matter is of course always a delicate one, often too nicely elaborated, as it may have been in the present instance; but, making due allowance for difference of opinion, the reality and importance of some of the corrections cannot be ignored.

Fourthly, there is no general investigation of the star-places. How satisfactorily Mr. Muller has dealt with this subject may be judged by consulting pp. 46–48 of his paper.

Fifthly, the few observations which appeared after Muller's computation was finished would affect the result to only a minute extent. It may be added, that his seven normals rest on 288 right-ascensions and 285 declinations, and Abetti's on 276 right-ascensions and 273 declinations.

To sum up; Mr. Muller's determination, in its conscientious, thorough and legitimate treatment, is entitled to be regarded as definitive in every sense in which that term can be employed; while it does not seem to me that Mr. Abetti's is of a class which can invite the unfortunate comparison which he has made.

Cambridge, Mass., 1891 *Feb.* 3.

FILAR-MICROMETER OBSERVATIONS OF COMET *d* 1890 (D'ARREST),

MADE WITH THE 26-INCH EQUATORIAL OF THE LEANDER MCCORMICK OBSERVATORY OF THE UNIVERSITY OF VIRGINIA.

[Communicated by the Director.]

1890 local M.T.	✱	No. Comp.	☄ — ✱ Δα	☄ — ✱ Δδ	☄'s apparent α	☄'s apparent δ	log pΔ		Obs.
Nov. 6ᵈ 7ʰ 7ᵐ 28ˢ	1	5 , 4	—0ᵐ 50ˢ.52	+4′ 9″.2	21ʰ 17ᵐ 32ˢ.19	—27° 27′ 28″.6	9.091	0.900	P
7 53 53	2	3 , 2	—0 43.42	+0 11.3	. . . .	. . . .	9.350	0.888	S
8 3 4	1	3 , 2	—0 41.98	+1 27.8	21 17 40.73	—27 27 10.0	9.384	0.885	S
15 7 30 55	3	4 , 3	—2 39.65	+3 14.9	21 50 39.91	—26 12 4.6	9.253	0.890	P
7 30 55	4	4 , 2	—2 13.68	+2 12.9	21 50 39.95	—26 12 8.2	9.253	0.890	P

Mean Places for 1890.0 of Comparison-Stars.

✱	α	Red. to app. place	δ	Red. to app. place	Authority
1	21ʰ 18ᵐ 20ˢ.85	+1ˢ.86	—27° 31′ 39″.9	+2″.1	W. Arg. 16792
2	21 18 22	+1.86	—27 27	+2.1	Anonymous
3	21 53 17.70	+1.89	—26 15 22.8	+3.3	W. Arg. 17137
4	21 53 21.71	+1.89	—26 14 21.4	+3.3	W. Arg. 17138

S = Ormond Stone; P = N. M. Parrish.

Nov. 6. Two condensations noticed by both observers. Principal condensation followed; and was situated about ⅓ distant from following edge of comet to center; the other was near the center.

Nov. 15. Nucleus well seen.

NEW ASTEROIDS.

The telegraph-cable reports the discovery of asteroids, by Charlois, Feb. 14 and 16, Millosevich, Feb. 12, a
Palisa, Feb. 14, in the positions: —

No. 302. 12ᴹ, Feb. 14.4088 Greenw. α = 9ʰ 51ᵐ 35ˢ.1, δ = +14° 53′ 38″. Daily motion, —52ˢ in α, and 1′ northw
No. 303. 12ᴹ, Feb. 12.5037 Greenw. α = 9 51 27.2, δ = +16 52 11. Daily motion, —52ˢ in α, and 5′ northward.
No. 304. 13ᴹ, Feb. 14.575 Greenw. α = 10 33 8, δ = + 6 16. Daily motion, —48ˢ in α, and 8′ northward.
No. 305. 11ᴹ, Feb. 16.6291 Greenw. α = 9 41 32.0, δ = + 7 2 21. Daily motion, —48ˢ in α, and 5′ northward.

NEW ASTRONOMICAL WORK.

Erstes Münchener Sternverzeichniss enthaltend die Mittleren Oerter von 33082 Sternen. Herausgegeben von Hugo Seeliger *und* Julius Bauschinger. *München*, 1890.

This volume, the first of the New Munich Annals, presents, as the Editor remarks, almost the total result of the astronomical activity of the Munich Observatory during the period 1840–1880. It contains a complete catalogue, for the epoch 1880, of star-positions derived from Lamont's zone observations, published in thirteen volumes, found in the series of Munich *Observationes Astronomicae* and *Annalen* from Volume XI of the former to Supplement-volume XIV of the latter. These observations, some 75 000 in number, had been reduced to the epoch 1850, and printed in catalogue-form in the Supplement-volumes V, VIII, IX, XI, XII, XIII and XIV, but these separate catalogues were regarded by Lamont himself as only provisional. The revision, preparatory to the publication of a general catalogue of all the observations, had been begun by him.

The transit-circle, which was regarded as an excellent one at the time of its construction, seventy years ago, was adapted to the purposes of zone-observation through the attachment of an auxiliary arm with a declination-scale attached to the telescope. This apparatus is described in the Introduction to the present catalogue. The employment of this arrangement, together with the use of a faulty chronograph (after 1850, when the eye-and-ear method was abandoned), and an indifferent clock, taken in connection with the arrangement of the observations of standard stars, are apparently responsible in great measure for the existence of the very large and irregular systematic discrepancies in Lamont's zone-observations as originally produced. (See *V.J.S.* Vol. IX, p. 94 ff.).

Lamont himself calls attention to these discrepancies (Suppl. B, V, pp. iii and iv, and elsewhere), and attempts to remove them by corrections determined through the comparison of zones, one with another; remarking, at the same time, that these zone-observations are suited only to a reduction on strictly differential principles, by which the clock and instrumental corrections shall be derived from the zone-observations themselves. This process, for reasons unnecessary to state, has remained difficult of practical execution up to the present time; and Professor Seeliger, when the manuscript of the contemplated general catalogue came into his hands in 1880, found that it would not be consonant with the means at his command to undertake the revision of the work on this rigorous plan. He therefore adopts the reductions as already made with the corrected zero-points as determined by Lamont, and sets before himself the task of eliminating, so far as possible, the numerous errors of record and reduction which exist in the originals.

The extent of this task may be inferred from the statement of the editor (p. xvii) that an average of one in five star-positions was affected by an error either of observation or reduction; and these errors had nearly all been transferred to the manuscript of the general catalogue for the epoch 1880, as it existed in 1883. For about two-thirds of the catalogue-numbers the errors were sought out and, where possible, corrected through comparison with other star-catalogues. There remained something less than 10 000 numbers for which no such means for rectification was sufficient, or existing; and these were all reobserved at the Munich Observatory in the years 1881–1888, — the results to appear in a later volume of the New Annals. This process led to the astonishing discovery that more than one-third of the older observations, so examined, were affected by material errors of observation or computation. This section of the work, alone, necessitated an examination of the original records in about 5200 individual cases.

A catalogue of those positions for which no corresponding star can now be found in the sky, under any reasonable assumption as to error in the original record, is presented on p. xx of the Introduction.

Pages xxii to xxxvi are dedicated to a very extended and detailed comparison of the Munich catalogue for 1880 with those of Argelander (Bonn VI), Schjellerup, Copeland and Börgen, and Gould (General Catalogue). The mean (inferred) deviation from the Auwers system, AG. — M., is found to be

$$\Delta\alpha = +0^{s}.02; \quad \Delta\delta = -1''.3;$$

but the systematic discrepancies from north to south, and from hour to hour, vary in a very perplexing way. These variations are in fact so large and so irregular as to destroy confidence in any systematic correction whatever of these observations which is not determined from the individual peculiarities of each zone.

Professor Seeliger omits the determination of the casual probable error of observation, and quotes that obtained by Argelander, $\pm 0^{s}.110$ and $\pm 1''.53$ (*V.J.S.*, IX, p. 113), with the remark that these quantities for the new catalogue would probably be found less.

The catalogue contains 33 082 numbers, and exhibits in successive columns the current number, the magnitude (regarded by the editor as of very little value) the R.A. for 1880 with the number of observations and the precession, the corresponding quantities for declination, the mean epoch of observation, and a reference by initials to other catalogues. Reference to the individual zones of Lamont is not included.

The catalogue brings out very clearly the uneven distribution in R.A. of Lamont's observations. The mean number per hour is 1378; while the average for the first eight hours is 370, and for 4^{h} the number is only 94. On the other hand, from 18^{h} to 21^{h} inclusive the average number per hour is 3719.

The catalogue is followed by copious notes, mostly concerned with errors detected in the published zones. The work bears throughout evidence of the painstaking care and thoroughness with which the editors have performed the task set before them.

CORRIGENDA.

No. 233. p. 135, col. 2, 2d line after table. *for* star *put* slow,

No. 235, p. 146, in equation (7), *for* e' *put* e'^{2}.

p. 150, col. 2, last line. *for* June 20 *put* January 20.

No. 236, p. 156, col. 2, line 8. log e. *for* 9.96727478 *put* 9.6727478.

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A METHOD FOR DETERMINING THE COLLIMATION OF THE PORTABLE TRANSIT INSTRUMENT,

BY MILTON UPDEGRAFF.

The chief difficulty in the accurate use of the portable transit-instrument lies in the determination of the collimation constant. Since observations over mercury, or the use of opposed collimators are either inaccurate or wholly impossible, all really practicable methods for determining the collimation of instruments of this class involve reversal; and either depend, or do not depend, on the assumption that the azimuth is the same before and after reversal. Even in case of instruments furnished with reversing apparatus there is some risk of disturbing the azimuth in reversing; and, when the instrument has to be reversed by hand, there is great danger of disturbing the azimuth even when the greatest care is exercised. Aside from this, a gradual change of azimuth during the observations is not at all unusual. For these reasons those processes are to be preferred which are independent of the azimuth, and the following accurate method for getting the collimation from the time-stars is offered in the belief that it will be found on trial to be very convenient and useful.

Let it be assumed at the outset that the rate of the clock or chronometer, and also the correction to the level-constant, due to inequality of pivots, are known. The instrument being approximately adjusted in collimation and azimuth, the inclination of the axis will be determined at short intervals with the spirit level.

Observe a group of time-stars, and one or more circumpolar stars, *Clamp West*, and a similar group, *Clamp East*. The time-stars should be within 45° of the equator, and the circumpolars within 20° of the pole. The best results are given by circumpolar stars lying between declinations 75° and 85°.

Reduce the observations, *Clamp W.*, by MAYER's formula, applying corrections for level, clock-rate and diurnal aberration in the usual manner, but assuming that the collimation is zero, and deducing provisional values for the azimuth a, and the clock-correction ΔT. Reduce the observations, *Clamp E.*, separately in the same way.

Let us designate the mean of the provisional ΔTs from the time-stars, *Clamp W.* and *Clamp E.*, by ΔTw and ΔTe, and the unknown collimation, *Clamp W.*, by c: then the collimation, *Clamp E.*, will be $-c$, assuming that the collimation remains constant during the observations. Then, unless $c = 0$, in fact, ΔTw and ΔTe will differ by a certain quantity D; and since all possible corrections have been applied, except that for collimation, this discrepancy D must be regarded as resulting from the change of sign of the collimation, and we shall have

$$\Delta Te - \Delta Tw = D = f(c).$$

We now proceed to discover the form of $f(c)$, considering first the observations, *Clamp W.* For each star observed we shall have an equation of the form,

$$\Delta T = \alpha - T - aA - bB - cC + \cos\varphi\,(0^s.021)\,C.$$

in which ΔT, a, b and c represent the true values of the instrumental and clock constants, α the apparent right-ascension of the star, T the observed time, and in which the transit-factors A, B and C have the following values:

$$A = \frac{\sin(\varphi-\delta)}{\cos\delta}, \quad B = \frac{\cos(\varphi-\delta)}{\cos\delta} \text{ and } C = \frac{1}{\cos\delta}$$

(*See* CHAUVENET's *Spherical and Practical Astronomy*, Vol. II, p. 145.)

Since α, T, bB and $\cos\varphi\,(0^s.021)\,C$ are known quantities, this equation may be written,

$$\Delta T = -aA - cC + M$$

in which $M = \alpha - T - bB + \cos\varphi\,(0^s.021)\,C$. Let an equation of this form be written for each of the time-stars. Adding like terms, and taking the means of the coefficients and absolute terms, we shall have an equation representing the time-stars, *Clamp W.*,

$$\Delta T = -aA_t - cC_t + M_t \qquad (1)$$

For any two stars, at least one of which must be a circumpolar, used for determination of azimuth, we may write,

$$\Delta T = -aA_1 - cC_1 + M_1$$
$$\Delta T = -aA_2 - cC_2 + M_2$$

from which

$$a = -c\,\frac{C_1 - C_2}{A_1 - A_2} + \frac{M_1 - M_2}{A_1 - A_2} \qquad (2)$$

Or equation (1) might be combined with the equation of a polar star for azimuth.

Differentiating equations (1) and (2)

$$D_c\Delta T = -A_t D_c a - C_t$$

$$D_c a = -\frac{C_1 - C_2}{A_1 - A_2}$$

or,
$$D_c\Delta T = A_t\frac{C_1 - C_2}{A_1 - A_2} - C_t = Kw$$

Now $D_c\Delta T$ can be computed from this formula, using the known transit factors which have already been used in the preliminary reduction in which the collimation was assumed equal to zero. Putting $D_c\Delta T = Kw$, we have this equation,

I
$$\Delta T = \Delta Tw + c\,Kw$$

In exactly the same manner the value of $D_c\Delta T$ for the observations, *Clamp E.*, may be found, and we have

II
$$\Delta T = \Delta Te - c\,Ke$$

Eliminating ΔT,

III
$$c = \frac{\Delta Te - \Delta Tw}{Ke + Kw}$$

and from equations I, II and III, the values of c and ΔT may be found.

In computing Kw and Ke, the formulas, *Clamp W.* and *Clamp E.*, are the same. $D_c a$, or $\frac{C_1 - C_2}{A_1 - A_2}$ may be computed separately for each circumpolar star by combination with the equation for the mean of the time-stars. Then the resulting values of Kw and Ke may be weighted, according to the judgment of the observer, in deriving the values of these quantities to be adopted in equations I, II and III.

If it is desired to determine the value of ΔT for each star, it can readily be done by correcting the provisional value of ΔT for each star, as follows:

$$\Delta T_1 = \Delta T' + cK'\ Clamp\ W.$$
$$\Delta T_1 = \Delta T' - cK'\ Clamp\ E.$$

in which ΔT_1 is the true value of ΔT for the star, $\Delta T'$ the provisional value found in the preliminary reduction, and $K' = A\,\frac{C - C_2}{A_1 - A_2} - C$. A and C are, of course, the transit-factors for the star.

The true value of the azimuth may be found from the formula

$$a = a' - c\,\frac{C_1 - C_2}{A_1 - A_2}$$

in which a' is the provisional value of the azimuth from the stars in question, and C_1, C_2, A_1, A_2 are the transit-factors of the stars used in deriving the azimuth.

If a complete check on the work is required, the reductions may be repeated from the beginning, using the value of the collimation given by equation III. The resulting value of ΔT should be the same as that derived from equations I and II.

When the rate of the clock is unknown, the instrument may be reversed again, and an additional group of stars observed. Then the rate may be found from the observations made in the 1st and 3d positions of the instrument, and a correction for it applied in the preliminary reduction.

By substituting the values of A_1, A_2, C_1 and C_2 in the expression for $D_c a$, we get

$$\frac{C_1 - C_2}{A_1 - A_2} = \sec\varphi\,\frac{\cos\delta_2 - \cos\delta_1}{\sin(\delta_2 - \delta_1)}$$

In the Report of the U.S. Coast and Geodetic Survey for the year 1874, there is a general table of the transit-factors A, B and C, for all latitudes and all declinations, which will be found very useful in case a table of transit-factors for the latitude of the place of observation has not been already computed.

Observatory of the State University of Missouri, 1891 *March* 3.

OBSERVATIONS OF THE VARIABLE *U PISCIUM* (CH. 466),

BY S. D. TOWNLEY.

[Communicated by Professor COMSTOCK, Director of the Washburn Observatory.]

In the *Astronomical Journal*, no. 235, there is an article by Mr. PARKHURST concerning the period of the variable star *U Piscium* (466). From a discussion of his own observations and those of Dr. PETERS, the writer obtains the period, $172.2\,E - 0.33\,E^2$, from which he obtains a maximum for the star, 1890 October 19.9. I have observed this star with the 15.5-inch equatorial of the Washburn Observatory, and have thirty observations of it; extending from 1889 Nov. 30 to the present time, with a break from March 10 to July 15. According to my observations, the period deduced by Mr. PARKHURST is too small. Instead of a maximum coming on Oct. 19.9 it did not come until Nov. 24. Between Nov. 4 and Dec. 15 I have eight observations; and they all fall in nicely with the light-curve, and give a well defined maximum on Nov. 24. Upon Nov. 20 and Nov. 27, the brightness of the star was the same, and there can be but little doubt that a maximum came between those dates.

In Chandler's Supplement (*A.J.* 216), we find the following elements:

$$\left.\begin{array}{l}\text{Max. 1880 Jan. 10}\\ \text{Min. 1879 Oct. 12}\end{array}\right\} +173^{d}$$

This would bring a maximum 1890 Dec. 2, which more nearly corresponds to my observations. These elements give as residuals (O—C) for my maxima of 1889 Dec. 20 and 1890 Nov. 24, -1^{d} and -8^{d}, respectively; and for the minimum of 1890 Sept. 5, $+2^{d}$. The minimum of Sept. 5, and the maximum of Dec. 20 are based upon observations not sufficiently accurate, and not close enough together to make the results very reliable; but at the maximum of Nov. 24 the observations are so numerous that there can be but little doubt as to the accuracy of the determination. Mr. Chandler's elements are based upon observations covering nineteen periods of the star, and the period is probably correct within one or two-tenths of a day, and the epochs within four or five days.

In one other respect my observations do not bear out Mr. Parkhurst's statements. According to the article above referred to, the star is of the eleventh magnitude at maximum. According to the magnitudes which I have adopted for the comparison-stars, I found the brightness of this star at its last maximum to be $9^{M}.7$, and Chandler's catalogue gives 10^{M}. Twenty days before reaching its maximum, I saw the star plainly with the three-inch finder of the equatorial. There are a very few stars, visible with the finder, not given on the *Durchmusterung* charts, and I find my estimated magnitudes to agree very closely with those given in the *Durchmusterung*. My estimates of magnitudes are based upon the assumption that, when the seeing is fairly good and the moon not visible, the *minimum visibile* of the equatorial is about $14^{M}.5$, and of the finder $10^{M}.3$. On Jan. 9, 1891, Mr. Parkhurst gives the variable as $13^{M}.2$; on Jan. 13, my observations give $11^{M}.8$; and the star was decreasing in brightness at that time. Its minimum is between 14.5 and 15.0.

In one respect, however, my observations do confirm those of Mr. Parkhurst. I refer to the rapid decline of the star for a few days just after passing maximum. In both my observed maxima there is a decided bend in the light-curve at this part.

My observations are as follows:

Date	Observation	Resulting mag.	Remarks.
1889 Nov. 30.4	Estimated $10^{M}.5$	10.5	Not visible in finder; bright moon
Dec. 12.4	*b* 5 *a*	10.3	" " "
22.5	Trifle brighter than *a*	9.8	Hazy
24.4	*b* 6 *a*	10.2	At limit of vision in finder; seeing poor
26.5	*b* 5 *a*	10.3	Visible in finder
1890 Jan. 7.4	*b* 4 *a*	10.4	Not visible in finder
Feb. 8.4	Same as *h*	12.8	Seeing poor
14.3	*i* 7 *h*	13.2	
Mar. 8.3	Not visible	<14	*i* extremely faint; 20° from horizon
July 15.7	*f* 5 *c*	11.1	
23.6	Same as *f*	11.8	Seeing poor
Aug. 19.6	Estimated $13^{M}.5$	13.5	
Sept. 10.6	Only just visible	14.5	
22.5	Trifle brighter than *i*	13.8	
14.6	*f* 4 *c*	11.5	
Nov. 4.4	*b* 7 *a*	10.2	Visible in finder
10.6	$0^{M}.1$ fainter than *a*	10.1	
18.5	$0^{M}.1$ brighter than *a*	9.9	
20.3	*a* 2 *n*	9.7	Estimated $0^{M}.4$ brighter than *a*
27.4	*a* 2 *n*	9.7	
Dec. 6.4	*b* 7 *a*	10.2	
10.3	*b* 6 *a*	10.3	
11.3	*b* 1 *a*	10.4	Very faint in finder
23.3	*b* 3 *a*	10.5	
30.3	Same as *b*	10.7	Seeing very bad
1891 Jan. 2.3	Same as *c*	11.0	
13.3	Same as *f*	11.8	
Feb. 3.3	*i* 6 *h*	13.3	
5.3	*i* 5 *h*	13.4	
10.3	Same as *i*	14.0	

b 6 *a* means that the light of the variable was six-tenths of the way from *b* to *a*.

Where nothing is said with regard to the seeing it was fair or good.

Coordinates and Magnitude of Comparison-Stars.

	$^{\mathrm{M}}$	$^{\mathrm{s}}$	$'$
n	9.2	—21	—7
a	10.0	+19	+5.0
b	10.7	+41	+2.3
c	11.0	+13	—5.0
f	11.8	+12	+0.8
g	12.0	+10	0
h	12.8	+11	—2
i	14.0	+10	+2

Madison, Wis., 1891 *Feb.* 17.

a, b, c and f are the same as used by Dr. Peters, and given in *A.N.*, vol. 99, no. 2360.

The magnitudes are my own estimates and estimates from Peters's charts, except n, which is taken from the *Durchmusterung*, being DM. +12°, 169. Upon two occasions when the seeing was very good I have b marked as very faintly visible in the finder, so there is some reason to believe that perhaps it is brighter than its assigned magnitude. If this be so, then a is brighter than 10^{M}, which would bring the variable at maximum to $9^{\mathrm{M}}.5$, or brighter.

ON THE CALCULATION OF STAR-PLACES FOR ZENITH TELESCOPE OBSERVATIONS,

By HAROLD JACOBY.

The calculation of star-corrections (or reductions from mean to apparent place) for zenith-telescope work, can be conveniently carried out by the following method. The usual custom is to apply the Besselian formulas to all the stars observed. But the stars are observed in pairs, and the calculation of the latitude requires only a knowledge of the *mean* of the apparent declinations of the two stars of any pair. It is, therefore, obvious that there may be a saving of labor if we do not compute separately for each star, but proceed at once to the mean of the corrections for the two stars by a single calculation. In other words, I propose to reduce the observations of each pair for latitude, using simply the mean declinations of the stars for the beginning of the year; and then apply a correction to the latitude so obtained. This correction will obviously be the mean of the declination reductions belonging to the two stars.

Now let:

α_1, δ_1, be the right-ascension and declination for the southern star,

α_2, δ_2, be the same quantities for the northern star, and put

$$t = \tfrac{1}{2}(\alpha_2-\alpha_1) \qquad \zeta = \tfrac{1}{2}(\delta_2-\delta_1)$$
$$\alpha_0 = \tfrac{1}{2}(\alpha_2+\alpha_1) \qquad \delta_0 = \tfrac{1}{2}(\delta_2+\delta_1)$$

Then the reductions required by the declinations of the stars will be, respectively,

$$i\cos\delta_1 + \tau\mu'_1 + g\cos(G+\alpha_1) + h\cos(H+\alpha_1)\sin\delta_1$$
$$i\cos\delta_2 + \tau\mu'_2 + g\cos(G+\alpha_2) + h\cos(H+\alpha_2)\sin\delta_2$$

the mean of which may be written:

$$\begin{aligned} i\cos\delta_0\cos\zeta + \tau\mu'_0 + g\cos(G+\alpha_0)\cos t \\ + \tfrac{1}{4}h[\cos(H+\alpha_2)+\cos(H+\alpha_1)][\sin\delta_2+\sin\delta_1] \\ + [\cos(H+\alpha_2)-\cos(H+\alpha_1)][\sin\delta_2-\sin\delta_1] \end{aligned}$$

The last term of this expression may be put in the form

$$h[\cos(H+\alpha_0)\cos t\sin\delta_0\cos\zeta-\sin(H+\alpha_0)\sin t\cos\delta_0\sin\zeta]$$

which can be brought into a single term by the introduction of auxiliary quantities. In this way the above expression for the mean of the reductions is brought into the form:

$$i\cos\delta_0\cos\zeta+\tau\mu'_0+g\cos(G+\alpha_0)\cos t+h\,m\cos(H+\alpha_0+kt)$$

where m and kt are given by the equations:

$$\begin{aligned} m\sin kt &= \cos\delta_0\sin\zeta\sin t \\ m\cos kt &= \sin\delta_0\cos\zeta\cos t \end{aligned} \qquad (1)$$

This is quite rigorous, and will always give precisely the same result as would have been obtained by computing the corrections separately. Little would be gained, however, by the use of the above formulas as they stand. But simplifications can be introduced, owing to the fact that t is always small, and δ_0 equal to the latitude very nearly. We shall not introduce any appreciable error if we write, instead of equations (1):

$$\begin{aligned} k &= \cot\phi\tan\zeta \\ m &= \sin\delta_0\cos\zeta\cos t \end{aligned} \qquad (2)$$

We may accordingly take as the final formulas for the correction, which must be added to the latitude computed with the mean declinations for the beginning of the year,

$$\begin{aligned} k &= \cot\phi\tan\zeta \\ x &= \cos\phi\cos\zeta \\ m_0 &= \sin\delta_0\cos t \\ \Delta\phi &= i\,x + \tau\mu'_0 + g\cos(G+\alpha_0)\cos t \\ &\quad + h\,m_0\cos(H+\alpha_0+kt)\cos\zeta \end{aligned} \qquad (3)$$

It will be found in practice that these formulas can be computed as quickly as the star-correction of either one of the stars could be done separately. It will require but a very few minutes to tabulate x to three, and k to two, places of decimals, for each 5° of ζ from 0° to 25°. Log m_0 should be tabulated in a small table of double entry which will also require only a few minutes to construct; for it need only have three arguments for t, and the same number for δ_0.

We can then take x, k, and log m_0 (which are always positive) from the tables by simple inspection; and they are constant for each particular pair of stars, as they depend on the star's positions alone. This fact especially recommends the method in cases where the same pairs of stars are observed frequently through long periods of time. It is also evident that differential formulas, similar to those proposed by **Preston** (*Differential Method of Computing Star-Places*, by E. D. **Preston**, Appendix 13, U. S. Coast Survey, 1888), can be applied to this method, if desired. But the method alone, as here given, will abridge the star-correction work by one-half.

As an example, let us assume the following data:

$\phi = 40° \; 45'$, or the latitude of Columbia College.

Date = 1886 Nov. 2, Washington Mean Midnight.

$$\alpha_2 = 2^h \; 28^m.0 \qquad \delta_2 = 60° \; 45' \qquad \mu_0 = 0$$
$$\alpha_1 = 2 \;\; 10 \;.0 \qquad \delta_1 = 20 \;\; 35$$

The quantities from the *American Ephemeris* are:

$$G = 2^h \; 7^m.9 \qquad H = 3^h \; 7^m.3 \qquad i = 6''.17$$
$$\log g = 1.1944 \qquad \log h = 1.2899$$

The tables computed by (3) for $\phi = 40° \; 45'$, are:

For x and k

ζ	x	k
0°	+0.758	+0.00
5	0.755	0.10
10	0.746	0.20
15	0.732	0.31
20	0.712	0.42
25	+0.687	+0.54

For $\log m_0$

t	$\delta_0 = 40° \; 40'$	$40° \; 45'$	$40° \; 50'$
0	9.8140	9.8148	9.8155
5	9.8138	9.8146	9.8153
10	9.8136	9.8144	9.8151

In the present case:

$$\alpha_0 = 2^h \; 19^m.0, \quad t = +9^m.0, \quad \delta_0 = 40° \; 40', \quad \zeta = 20° \; 5'$$

and therefore from the little tables, by inspection, we have for this pair of stars:

$$x = 0.712 \qquad k = 0.42 \qquad \log m_0 = 9.8136$$

so that

$$kt = +3^m.8 \qquad \alpha_0 + kt = 2^h \; 22^m.8$$

$$\begin{aligned} g \cos(G+\alpha_0) \cos t &= \overset{''}{+6.18} \\ h m_0 \cos(H+\alpha_0+kt) \cos\zeta &= +1.55 \\ ix &= +4.39 \\ \Delta\phi &= +12.12 \end{aligned}$$

A calculation of the two stars separately gives for the respective reductions

$$10''.46 \qquad \text{and} \qquad 13''.79$$

whose mean is 12″.12, agreeing exactly with the result found above.

Columbia College, New York, 1891 *Feb.* 16.

ON THE LIGHT-VARIATIONS OF *X CYGNI*,

BY PAUL S. YENDELL.

From 1890 May 11 to 1891 Jan. 16, I have observed this star one hundred and forty times. From the single light curves resulting from this series of observations, fourteen maxima, and an equal number of minima are deduced, as follows:

	Maxima			Minima		
E	Date	w	O—C	Date	w	O—C
			d			d
81	'90 May 31.30*	4	+0.99	May 22.10	4	—1.40
82	June 15.25	5	+0.45	June 8.70	3	—0.10
83	30.50*	5	—1.59	25.30*	4	+0.11
84	July 17.60	5	—0.87	July 10.80	4	—0.77
85	Aug. 2.90	5	—0.96	27.40*	4	—0.56
86	19.60	4	—0.65	Aug. 14.20	5	+0.85
87	Sept. 5.20	5	—0.44	29.5*	5	—0.21
88	21.40*	5	—0.63			
89				Oct. 2.3	4	+0.78
90	Oct. 22.60	4	—2.20	17.7	4	—0.20
91	Nov. 10.6	5	+0.41	Nov. 3.2	5	—0.09
92	27.3	4	+0.72	19.6	5	—0.08
93	Dec. 13.0	5	+0.03	Dec. 7.8	1	+1.73
94	27.8	5	—1.56	19.3	3	—3.16
95	'91 Jan. 13.7	3	—1.04	'91 Jan. 7.5	5	—0.34

The residuals are obtained by comparison with the elements published by me in this *Journal*, Vol. IX, p. 188. Maxima and minima marked with an asterisk occurred during moonlight.

Especial attention has been paid to the fluctuation in range of the light-curve alluded to by **Chandler** in his papers in Vol. VII, pp. 32 and 159, and by myself in Vol. VIII, p. 177 and Vol. IX, p. 188. As a preliminary to a final investigation of this question, it seemed advisable to construct a light-scale of a quasi-definitive character, using for the purpose the whole body of observations accumulated during the three years I have had the star under observation; this scale, with the estimated magnitudes of the comparison-stars, are as follows:

Comparison-stars	L	Mag. Y
		M
a = DM. 35° 4141	13.6	6.2
b = DM. 34 4127	9.4	6.7
d = DM. 34 4111	7.0	6.9
f = DM. 34 4114	5.0	7.1

The value of a step, according to this scale, appears to be $0^M.091$, or $\frac{1}{11}$ mag.

The light-tables given in Vol. VIII, p. 178 and Vol. IX, p. 188, have been reduced to this scale, together with the maximum and minimum lights observed during the past season, and are embodied in the following table:

MAXIMUM AND MINIMUM AMOUNTS OF LIGHT, *X Cygni.*

E	Max.	Min.	Obs.	E	Max.	Min.	Obs.
3	12.0	4.0	C	60	12.6		Y
4	13.0	2.5*	“	61	14.2*	5.2	“
5		3.5	“	62	12.6	7.5*	“
6		3.5	“	63	13.6*	7.2	“
21	12.7		“	64	13.2	7.0	“
22	10.8		“	65		7.0	“
23	12.3	5.7	“	66	11.7	7.2	“
24	12.0	5.7	“	67	11.7	5.5*	“
25		2.5	“	68		5.2	“
37	11.2	6.8	Y	69	10.7	4.7*	“
38	12.0	6.7*	“	70	11.2*	2.8	“
39	12.8	6.7	“	71	11.7	3.9	“
40	13.6	7.0	“	72	11.2*	3.9	“
42	13.0	6.5*	“	73	11.2	5.0	“
43	13.6*	7.0	“	81	13.4*	6.8	“
44	11.7	6.15	“	82	13.5	7.2	“
45	11.7*	5.7	“	83	12.5*	6.5*	“
46	10.8	5.7	“	84	13.5	7.2	“
47	13.0	6.7*	“	85	12.5	6.5*	“
48	11.0	5.1	“	86	12.5	7.4	“
49	10.7	6.3	“	87	12.5	6.5*	“
50	9.4*	5.1	“	88	12.5		“
51	11.7*	5.7	“	89		7.2	“
52	11.0	6.0	“	90	10.5	5.0	“
53	12.0		“	91	9.5	3.0	“
58	11.7		“	92	9.4	3.5	“
59	13.6*	6.2	“	93	9.5	3.0	“
				94	10.5	4.0*	“
				95	10.5	4.0	“

Observers. C. = CHANDLER; Y. = YENDELL.

Upon plotting the above table, and drawing curves so as best to satisfy the observed lights, a very definite and regular variation, quite simultaneous for both maximum and minimum lights, is at once apparent; the period of this fluctuation appears to be twenty-one periods of the star's principal variation, or rather, perhaps, the star's principal variation appears to have a light-range of $0^{M}.4$ in a period of 344 days, on which is superposed a variation of from $0^{M}.4$ to $0^{M}.8$, with a period of 16.38 days. The maxima and minima of the great curve appear to succeed each other with much regularity for the three years during which I have had the star under observation; and CHANDLER's observations for 1886 and 1887 fall in well on its prolongation; we may, therefore, I think, regard the periodical character of this variation as distinctly proved.

Maxima on this curve have occurred as follows:

		Max. light	Min. light
Epoch	41	13.2	8.0
	62	13.5	7.2
	83	13.5	7.2
Minima			
Epoch	50	9.5	5.2
	71	10.8	3.0
	92	9.3	3.0

The star's average light-range appears to be $6^{st}.32 = 0^{M}.58$; the extremes observed are $4^{st}.3 = 0^{M}.39$, and $9^{st}.0 = 0^{M}.82$.

The average interval from minimum to maximum is $6^{d}.9$.

Greatest observed light, $14^{st}.2 = 5^{M}.7$; least, $2^{st}.8 = 7^{M}.3$.

Dorchester, Mass., 1891 *March* 8.

ON THE PERIOD OF *U ORIONIS*,

BY J. E. GORE, F.R.A.S.

With reference to Mr. CHANDLER's remarks on the period of this variable in the *Astronomical Journal*, no. 233, I have computed from my elements, 1887 Dec 22 $+373^{d}.47\,E$, the epochs of maxima which fall nearest to the dates of the old observations he quotes, and find the following results:

	Date of observation	Computed epoch of maximum	Difference days
(1)	1797 Feb. 17	1796 Dec. 19	60
(2)	1826 Mar. 3	1826 Aug. 16	166
(3)	1850 Dec. 30	1851 Mar. 1	61
(4)	1853 Nov. 6	1854 Mar. 25	139
(5)	1854 Nov. 24	1855 Apr. 3	130
(6)	1855 Feb. 18	1855 Apr. 3	44
(7)	1857 Feb. 9	1857 Apr. 19	69

My calculations have been checked by Lieut.-Col. MARKWICK, F.R.A.S., and his results agree with mine.

It will be seen that all the dates of observation (except no. 6) are sufficiently distant from the computed epochs of maxima to be quite consistent with my elements. As the star rises to a maximum more rapidly than it decreases in light, it would be probably below 9^{M} or fainter 60 days *before* a maximum (as in cases 3 and 7). With reference to no. 6 the star may very possibly have been faint at the maximum of that year, say $7^{M}.5$ (as it was at the maximum of Dec. 1887), and in this case it might well have been only $9^{M}.5$ on 1855 Feb. 18, as observed by SCHÖNFELD. On 1886 Nov. 1, or 44 days before the maximum (not a faint one), as observed by Mr. SAWYER, I found the star invisible in a clear moonless sky with my binocular, which shows stars to $8^{M}.8$ or 9^{M}. On 1888 Nov. 9, or 47 days before the maximum, it was also invisible with the binocular, in a very clear, moonless sky. Col. MARKWICK tells me that on 1890 Dec. 15, or about 28 days before the recent maximum, he found the star below $8^{M}.5$, and my observations confirm this. From the above consideration I conclude that my period of $373^{d}.47$ is quite as probable as any other.

Ballysodare, Ireland, 1891 *Feb.* 10.

EPHEMERIS FOR THE RETURN OF WOLF'S PERIODIC COMET 1884 III.

Dr. Berberich has very kindly computed for me an ephemeris of Wolf's periodic comet (1884 III).

As no ephemeris has so far been published for the apparition of the comet this year, I take the liberty of sending Dr. Berberich's elements and ephemeris to the *Journal*, so that others may have an opportunity to join in the search.

Mt. Hamilton, 1891 *Feb.* 9.

E. E. Barnard.

ELEMENTS AND EPHEMERIS OF COMET 1884 III (*WOLF*),

By Dr. A. BERBERICH.

Elements.

Epoch, 1891 Sept. 8.0 Berlin M.T.

$$M = 0^\circ\ 35'\ 50''.7$$

$$\left.\begin{aligned} \omega &= 172\ 49\ 17.3 \\ \Omega &= 206\ 21\ 35.5 \\ i &= 25\ 14\ 37.5 \end{aligned}\right\} \text{Mean Eq. 1890.0}$$

$$\varphi = 33\ 51\ 25.8$$

$$\mu = 520''.2349$$

$$\log a = 0.5558714$$

$$T = \text{Sept. } 3.86591 \text{ Berlin M.T.}$$

Ephemeris for Berlin Midnight.

1891		App. α			App. δ		log Δ	Br.
		h	m	s	°	′		
May	3	22	31	40	+13	3.9	0.3593	1.32
	7		40	19	14	0.6		
	11		49	4	14	57.4	0.3401	1.51
	15	22	57	54	+15	54.2		
May	19	23	6	51	+16	50.9	0.3204	1.73
	23		15	59	17	47.3		
	27		25	4	18	43.1	0.3001	1.98
	31		34	21	19	38.1		
June	4		43	45	20	32.0	0.2793	2.27
	8	23	53	17	21	24.7		
	12	0	2	57	22	15.8	0.2580	2.62
	16		12	45	23	5.0		
	20		22	40	23	52.0	0.2362	3.00
	24		32	44	24	36.6		
	28		42	56	25	18.4	0.2139	3.45
July	2	0	53	15	25	57.3		
	6	1	3	42	+26	32.2	0.1911	3.96

Variation corresponding to -1^d in the period.

May 11 +96s. +1′.4.
June 20 +133s. −2′.3.

ELEMENTS OF COMET 1890 IV (*ZONA*).

By EDWIN B. FROST.

From the three normal places derived from the observations on Nov. 18 at Rome and Dresden, on Dec. 8 at Strassburg and Bordeaux, on Dec. 28 and 29 respectively at Bordeaux and Dresden, I have computed the following elements.

$$T = 1890 \text{ Aug. } 7.1914 \text{ Berlin M.T.}$$

$$\left.\begin{aligned} \pi - \Omega &= 331^\circ\ 21'\ 47''.3 \\ \Omega &= 85\ \ 22\ \ 40\ .3 \\ i &= 151\ \ 19\ \ \ 2\ .4 \end{aligned}\right\} \text{Mean Equinox 1890.0}$$

$$\log q = 0.311363$$

$$\text{O}-\text{C}: \quad \delta\lambda' \cos\beta' = -0''.3. \qquad \delta\beta' = +3''.4.$$

Strassburg, 1891 *March* 2.

ON THE REFRACTION-CORRECTION OF PHOTOGRAPHIC MEASURES.

By S. C. CHANDLER.

The final formulas of Mr. Jacobi in the last column of p. 164, no. 237, are rather troublesome and complicated, as he, indeed, recognizes in proposing to reduce the labor of their computation by constructing tables. I would suggest, however, that this is entirely unnecessary, as the corrections in question may be expressed in very simple functions of the refractions themselves. Thus, if $\sigma - s$ and $\pi - p$ are the refractions computed by Bessel's formulas with the coordinates of the center of the plate, the corrections to be applied, to get the values which would have been obtained by using the coordinates for the middle points between the center and the several stars, may be obtained very simply from.

$$\begin{aligned} \Delta(\sigma - s) &= -\ s(\sigma - s)\ \sin 1''\ \sec\zeta\ \cos(p-q) \\ \Delta(\pi - p) &= -\tfrac{1}{2}\, s(\pi - p)\ \sin 1''\ \sec\zeta\ \cos(p-q) \end{aligned} \tag{1}$$

The errors of these approximate expressions are excessively small, and in all ordinary cases entirely negligible.

Cambridge, 1891 *Feb.* 27.

With very large zenith distances and high declinations we may employ the following:

$$\begin{aligned} \Delta(\sigma - s) &= -s(\sigma - s)\ \sin 1''\ \cos(p-q) \\ &\qquad [\sec\zeta - \tan\delta\ \sin p\ \sin(p-q)] \\ \Delta(\pi - p) &= -\tfrac{1}{2}\, s(\pi - p)\ \sin 1''\ \cos(p-q)\ (1 + \tan^2\zeta) \\ &+ \tfrac{1}{2} s\kappa \sec^2\zeta \tan\delta\, [\sin p(\cos^2 q + \cos 2(p-q)) - \cos^2 q] \end{aligned} \tag{2}$$

where only terms of the order of squares of the refractions are neglected.

The approximate formula (1) for position-angle will be somewhat more accurate if we put $1 + \tan\zeta$ for $\sec\zeta$.

I would add that it is my impression, without such examination as is needed to make sure, that some of the terms in the article of Mr. Jacobi are illusory, being of the same order as those neglected in the assumption that the exposures are instantaneous, which is not practically true.

NEW ASTEROIDS.

Two other small planets, 13^M, were discovered by **Millosevich**, March 1, and **Charlois**, March 5, in the following positions:

No. 307. Mar. 1.4681 Gr. M.T. $\alpha = 10^h\,47^m\,29^s.3$, $\delta = +11^\circ\,36'\,40''$. Daily motion, — 1^m in α, and $11'$ northward.
No. 308. Mar. 5.3455 Gr. M.T. $\alpha = 10\;\;1\;\;26.1$. $\delta = +19\;\;42\;\;10$. Daily motion, -48^s in α, and 4 northward.

Prof. **Krueger** gives notice that an asteroid observed by **Charlois** 1890 Nov. 14, and supposed by him to be no. 298, discovered Sept. 9, proves not identical with the latter. Consequently it takes the number 302; and the numbering of the four announced on p. 167 of the *Astronomical Journal* must be increased by 1 in each case.

Names have been given, as follows, to asteroids heretofore discovered:

283 *Emma*	285 *Regina*	290 *Bruna*	292 *Ludovica*	294 *Felicia*
284 *Amelia*	289 *Nenetta*	291 *Alice*	293 *Brasilia*	295 *Theresia*

COMETS OF THE YEAR 1890.

The dates are in Greenwich Mean Time, and the Elements only approximate.

Designation	Perihelion	☊	ω	i	q	ϕ	Discoverer	Date	Synonym	
		° ′	° ′	° ′		° ′				
I	Jan. 26.480	8 29	199 52	56 45	0.270		Borrelly	1889 Dec. 12	*g* 1889	
II	June 1.467	320 21	68 54	120 34	1.908		Brooks	1890 Mar. 19	*a* 1890	
III	July 8.649	11 25	85 53	63 15	0.766		Coggia	July 18	*b* 1890	
IV	Aug. 7.093	85 23	331 19	154 18	2.047		Zona	Nov. 15	*e* 1890	
V	Sept. 16.	146 5	172 58	15 43		38 50	Barnard	Oct. 6	*d* 1890	d'Arrest's
VI	Sept. 24.478	100 7	163 0	98 56	1.260		Denning	July 23	*c* 1890	
VII	Oct. 26.564	45 6	12 51	12 51	1.818	28 8	Spitaler	Nov. 16	*f* 1890	Period $6^y.4$

NEW ASTRONOMICAL WORK.

Catalog von 3919 *Sternen zwischen* 64° 50′ *und* 70° 10′ *nördlicher Declination* 1855, *für das Aequinoctium* 1875, *nach Zonen-beobachtungen am Ertelschen Meridiankreise der Universitäts-Sternwarte in Christiania in den Jahren* 1870 *bis* 1881 *von* C. **Fearnley** *und* H. **Geelmuyden**. *Leipzig*, 1890. 80 pp. 4to.

This contains the third part of the first division of the zone-catalogues of the *Astronomische Gesellschaft*, and is the third to make its appearance, the parts undertaken at Albany and at Helsingfors-Gotha having already been published. The observations were made with the Ertel Meridian-Circle of 48 lines aperture and five feet focal length, and have been already published in zone form in *Zonen-beobachtungen der Sterne zwischen* 64° 50′ *und* 70° 10′ *u.s.w.* The transits were observed by the eye-and-ear method, usually over four threads, by Professor **Fearnley**, and the circle-readings were obtained from two verniers by Professor **Geelmuyden**. The observations were made about equally in the two positions of the circle, east and west. A comparison shows that, while for right-ascension the difference, E.–W., is of no importance, this difference for the declinations varies from $-0''.07$, in 12^h of R.A., to $-1''.36$, in 9^h, and is in the mean about $-0''.80$. The observations are arranged in five groups, according to right-ascension, and one-half the difference thus ascertained is applied to the circle-readings in the respective positions with opposite signs. The largest difference is $-1''.12$ ($20^h\,56^m$ to $10^h\,35^m$), and the smallest $-0''.35$ ($15^h\,59^m$ to $18^h\,39^m$). It was found necessary to apply also a correction of $-0''.54$ to the declination obtained from lower culmination. Special corrections in declination for a few zones have been determined through comparison of their places with those of other zones. These corrections vary between $-1''.85$ and $+2''.36$. Only half weight is assigned to the declinations from certain zones. The probable error of a single determination is given as $\pm 0^s.054$ in right-ascension ($\pm 0^s.02$ in great circle), and $\pm 0''.54$ in declination. The arrangement of the catalogue is the same as that for the numbers of the series which have already appeared, except that columns are added in which are given the coefficients of precession which depend upon the third power of the time; and notes relating to proper motion appear at the foot of the catalogue-page.

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Ephemeris for the Return of Wolf's Periodic Comet 1884 III, by Prof. E. E. Barnard.
Elements of Comet 1890 IV, by Mr. Edwin B. Frost.
On the Refraction-Correction of Photographic Measures, by Mr. S. C. Chandler.
New Asteroids.
Comets of the Year 1890.
New Astronomical Work.

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SOUTHERN VARIABLE STARS OBSERVED IN 1889 AND 1890.

BY JOHN G. HAGEN, S.J.

In the Smithsonian Report for 1866, pp. 380-381, expression was given to our intention of devoting the old equatorial to variable-star work. It is a TROUGHTON and SIMMS instrument of about 5 inches aperture, and it was supposed that the position of the observatory would be favorable for work on stars south of the equator.

The present paper contains the results of the work of the last two years, at least as regards those phases which have been completely determined.

The majority of these stars have been little observed since the publication of Professor SCHÖNFELD's second catalogue, probably on account of their southern declination and comparative faintness. This would seem to justify the original plan.

In the following pages the fractions of days are expressed in *Greenwich Mean Time*, and all the magnitudes reduced to the scale of the *Southern Durchmusterung*.

The *maximum brightness* of the stars was derived, not from single estimates, but from the light-curve, nor was it based on the magnitudes of the brightest comparison stars alone, but on a reduced magnitude scale depending on all the estimates made, and expressing the *mean* SDM. scale in the small field around the variable, as has been more fully explained in a previous article on the light-variations of *S Persei* and *T Arietis* (*A. J.*, vol. X, pp. 116-118.)

The mean *step-value* in this equatorial seems to be considerably smaller than it was in the 3-inch glass which I formerly used, as the following figures will show:

1 step = $0^{\rm M}.108$, 3-inch equatorial, 1883–1888

1 step = $0^{\rm M}.016$, 5-inch equatorial, 1889–1890

The upper number was deduced from two variables and 133 estimates, namely *S Persei* and *T Arietis* (see the paper before mentioned), the latter from eleven variables and 289 estimates.

It may be useful to show how the step-value *varies* for the eleven constellations, that form the subject of this article.

No.	Star	1 Step	No. of obs.
845	*R Ceti*	$0^{\rm M}.045$	29
893	*U Ceti*	57	41
4407	*R Corvi*	75	26
4805	*W Virginis*	44	45
4816	*U Virginis*	56	18
4847	*S Virginis*	55	28
6132	*R Ophiuchi*	21	13
6905	*R Sagittarii*	19	18
6921	*S Sagittarii*	–	16
7468	*T Aquarii*	42	17
8230	*S Aquarii*	49	38

Average step = $0^{\rm M}.0463$; 289 observations on 145 nights.

The step-value seems to depend mainly on the range of the comparison-stars. It decreases as the intervals between the magnitudes of the comparison-stars become smaller, in accordance with the experience of other observers, like OUDEMANS and SCHÖNFELD.

This series of observations of southern variables will be discontinued for the present, since work of a wider scope has been initiated, an account of which will appear in due time.

845. *R Ceti.*

No observations of this star seem to have been published between 1875 and 1890. Two maxima have been observed here in 1890, the one deduced from 16 observations, as mentioned in this *Journal* (vol. IX, p. 158), the other from 13 observations between 1890 October 31, and 1891 January 25.

The single light-curves give these maxima approximately on the following days:

Max. 1890 Jan. 3-4, and Dec. 13.

Since both curves appear pretty regular, they have been combined into a mean light-curve, supposing the period to be 167.1 days. The 29 available observations gave 15 normal points, and, from the mean curve thus determined, the following scale of steps was derived:

Days	Steps	Days	Steps
—30	39.0	+10	9.3
—25	29.9	+15	13.7
—20	21.4	+20	17.4
—15	13.9	+25	21.0
—10	9.6	+30	24.6
— 5	8.0	+35	28.0
0	7.5	+40	31.5
+ 5	7.4	+45	35.2

The mean curve has the peculiarity that the highest point does not exactly coincide with the maximum as determined by Pogson's curve, a case which will appear more strikingly below in the curve of *S Aquarii.*

The steps may be reduced to the scale of the SDM. magnitudes by the following table:

Steps	Mag.	Steps	Mag.
7	8.23	23	8.95
9	8.32	25	9.04
11	8.41	27	9.13
13	8.50	29	9.22
15	8.59	31	9.31
17	8.68	33	9.40
19	8.77	35	9.49
21	8.86	37	9.58

Maximum brightness = $8^{\mathrm{M}}.2$.

By means of the mean light-curve the two maxima have been determined with greater exactness as follows:

E 42, *Max.* 1890, Jan. 4.5, O—C = —13.1 days
44, *Max.* 1890, Dec. 10.0, O—C = — 7.8 days

The periods have been counted and the residuals deduced from the elements in Prof. Schönfeld's catalogue:

Max. 1870, Oct. 31.4 + 167.1 *E*,

where it is stated that nine maxima between 1867 and 1875 would give the period 167.65 days, with large and regular errors up to 10 days. The period was diminished to 167.1 in the catalogue on account of preceding observations as far back as 1794, whilst the two latest maxima 1890 seem to require a still smaller period of about 166.9 days. More numerous observations will be necessary to show whether the variations are regular and periodic.

893. *U Ceti.*

Two maxima of this star were observed in 1890, the one in February, the other in October. The light-curve of the first maximum rests on 23 observations from 1889 Dec. 12, until 1890 March 8, and shows great irregularities, probably due to the observations alone. The maximum brightness = $7^{\mathrm{M}}.6$ was apparently reached between Feb. 3 and 5.

The same maximum was observed by Mr. Sawyer (*A. J.*, vol. X, p. 14) and put on Feb. 7.5. As a mean value we may take Feb. 6 for the time of maximum.

The other light-curve is very regular and gives the maximum on Oct. 9, magnitude = $7^{\mathrm{M}}.6$, from 18 observations between 1890 August 25 and Dec. 13.

There are only three well-determined maxima recorded, prior to those mentioned, all by Mr. Sawyer (*A. J.*, vol. VII, p. 185, and vol. VIII, p. 170).

The following table shows all the five *maxima*, with the results that can be drawn from them:

E	Maximum.	Wt.	O—C	Observer
—3	1886 Nov. 26	1	$+8^{\mathrm{d}}$	S.
—1	1888 Feb. 24	1	—8	S.
0	1888 Oct. 22	1	—3	S.
+2	1890 Feb. 6	2	—2	S., H.
+3	1890 Oct. 9	1	+7	H.

Five equations of condition were formed, which gave, by the method of least squares, the following *elements:*

Maximum, 1888 October 24.9 + 235.55 *E*; *magnitude* = 7.6, with the *residuals* in the column O—C.

4407. *R Corvi.*

A well-determined maximum was obtained from 26 observations, commencing 1890 February 13 and ending June 14:

$$E\ 22\ Max.\ 1890\ \text{Mar}\ 29,\ 5^{\mathrm{M}}.9,\quad \text{O—C} = \begin{cases} +28 \text{ days (Sch.)} \\ +30 \text{ days (Ch.)} \end{cases}$$

The increase of light was somewhat more rapid than its decrease.

The maximum occurred about a month later than was expected from the elements in Schönfeld's and Chandler's catalogues, the *mean* value of the 22 periods between 1870 and 1890 being as large as 319.86 days.

There is a maximum recorded by Prof. Schönfeld (*A. N.* 2065) on 1875 May 3, and two more recent ones in this *Journal* (vols. VIII and IX) for 1888 and 1889, approximately determined from 5 and 6 observations by Mr. Sawyer and Mr. Yendell respectively.

Some more well-determined maxima, however, will be required before the *periodical inequality* to which the light-variations of this star are evidently subject (see Mr. Chandler's Catal. pp. 83 and 87), can be determined mathematically.

4805. *W Virginis.*

No observations of this star appear to have been published since the discussion of the elements by Prof. Schönfeld (*A. N.* Nos. 1729 and 1931), except three or four maxima by Mr. Yendell (*A. J.*, vol. IX, p. 83) in 1889; owing probably to the peculiar difficulties attending this case. Two weeks of good weather are necessary for an independent determination of a maximum or minimum and the moon should not be full near the time of minimum brightness. The difficulty is increased by the proximity of bright stars and the great distance of convenient comparison-stars.

As will appear from the table below, column headed p = *weight*, there is only one case (E 449) within two years, in which 13 observations could be secured for the same minimum.

Forty-five observations were obtained during 1889 and 1890, of which two had been marked doubtful and were rejected. The phases were derived from them, not by single light-curves, but by the method explained by Argelander in his first paper on β *Lyrae*. The 43 observations were combined into 15 normal points, which gave a light-curve resembling so closely that of Prof. Schönfeld, that no change can be detected for the course of the last twenty years.

The following table will represent the resulting phases:

E	Phase	Obs. Greenw. M.T.	p	O—C	O—C′
423	Min.	1889 Apr. 18.5	1	—0.3	
423	Max.	26.8	3	—0.2	+1.0
424	Min.	May 6.1	2	0.0	
424	Max.	13.9	3	—0.4	+0.8
441	Min.	1890 Feb. 23.3	4	—0.4	
442	Max.	Mar. 21.0	6	—0.2	+1.0
444	Min.	Apr. 15.5	8	—1.0	
447	Max.	June 15.2	2	—0.3	+0.9
449	Min.	July 11.3	13	—0.6	

The *periods* in the first column are counted from Schönfeld's epoch:

$$\left.\begin{array}{l} \textit{Min.}\ 1869\ \text{April}\ 17.466 \\ \textit{Max.}\ 1869\ \text{April}\ 25.666 \end{array}\right\}\ \text{(reduced to Greenwich M.T.)}$$

The fourth column gives the *weight* equal to the number of observations. The weights of the phases in 1889 are so small that they can have little influence in a recomputation of elements, and they have been added merely to show the general prevalence of the negative sign.

The fifth column gives the differences between the dates observed and those computed from Prof. Schönfeld's period = 17.27263, and the last column the same computed from Mr. Yendell's = 17.26987.

As appears from the signs of the residuals, the *mean period* from 1869 up to 1890 has a value between those just mentioned. We can get an approximation of this value in the following way:

The mean (by weights) of the residuals O—C divided by the mean of the corresponding epochs E gives:

$$-\frac{0.507}{441} = -\ 0.00115 \text{ days,}$$

and this quantity added to 17.27263 gives the

$$\textit{Mean Period} = 17.27148 \text{ days } (E\ 441)$$

The maximum and minimum *brightness* of the star, as derived from the mean light-curve, are as follows:

$$\textit{Max.} = 8^{\rm M}.9, \quad \textit{Min.} = 9^{\rm M}.5.$$

4816. *V Virginis.*

In 1889 the star was found invisible between May 14 and April 22, or about the period 31.4, counting from Prof. Schönfeld's epoch:

$$\text{Max. 1867 Sept. } 4 + 251\ E.$$

In 1890 only 15 observations were obtained, from which a curve was drawn, giving approximately the following result:

E 33, Max. 1890, May 1; O—C = — 8 days.

The residual of 8 days does not point to an error in the elements, in view of the fact that deviations of the single light-curves from the computed maxima may amount to 10 days (see Schönfeld's II Catalogue, p. 45).

The *maximum brightness* reached by the star on this occasion was only $9^{\rm M}.2$.

4847. *S Virginis.*

In 1889 the star was observed three times, from March to April, and the observations only show that its brightness was near maximum.

In the following year 25 observations were obtained between February 15 and July 5, ten before and the rest after maximum.

Since the light-variations were rather rapid (more than 40 steps in three months), the maximum of the (single) light-curve could be determined exactly within a few days, as follows:

E 26, *Max.* 1890 March 29; O—C = + 37 days, *mag.* = 7.3, as referred to the elements in Mr. Chandler's Catalogue.

The large residual confirms the statement of Mr. Chandler in the introduction to his catalogue regarding periodical variations.

6132. *R Ophiuchi.*

Thirteen observations of this star were obtained in 1890 from August 15 to October 17, which gave the following maximum:

E 30, *Max.* 1890 Sept. 14, O—C = + 21 days, *brightness* = $7^{\rm M}.4$, with epoch and residual based on Schönfeld's elements.

The error of the single light-curve cannot be as much as ± 4 days, because of the rapid and regular change of light near maximum.

The *mean* period between 1865 and 1890 is 303.1 days.

6905. *R Sagittarii.*

This star was under observation on 18 nights from 1890 August 15 to November 18, and reached its maximum brightness between October 14 and 16, or, say:

E 29, *Max.* 1890 Oct. 15, O—C = —51 days, *brightness* = $8^{M}.0$.

The epoch and period from which these numbers were deduced, are Prof. Schönfeld's (based on 3 sure maxima within 7 periods):

Max. 1869 June 28, + 270 *E*.

The light-curve appears very regular, the increase of brightness being as usual a little more rapid than the decrease.

There is a maximum mentioned in the *A.N.* (No. 2066) by Prof. Schönfeld on 1871 Sept. 13, with a residual O—C = +13 days.

The maximum of 1890 seems to be sure within two or three days, and the large residuals +13 and —51 point to considerable irregularities.

The numerous observations of this star by Prof. Safarik, between the years 1883 and 1887 will be invaluable in a recomputation of the elements, when reduced and published.

The *mean period* between 1869 and 1890 seems to be 268.24 days.

6921. *S Sagittarii.*

This star has not been much observed, on account of its faintness. In 1890 the star was observed here on 16 nights, from Aug. 15 until Nov. 13, starting from Prof. Schönfeld's elements:

Max. 1869, Nov. 20 + 230 *E*,

we have, from a single light-curve, the following result:

E 33, *Max.* 1890 Oct. 16; O—C = +45 days; *mag.* = 9.7.

Hence, even assuming an error of 10 days in the last maximum, the *mean period* between 1869 and 1890 is one day longer than given above. Its nearest value we can get from this maximum is 231.4 days.

7468. *T Aquarii.*

A maximum has been determined here in 1890 from 17 observations between Sept. 15 and Nov. 28, namely:

E 17, *Max.* 1890 Oct. 19, O—C = $+7^{d}.6$, *brightness* = $8^{M}.7$.

The residual is computed from Mr. Chandler's elements, and does not, if considered by itself, indicate any change in the period. Yet it may be suggestive to compare it with the residuals of preceding observations. Starting from 1881 May 10.5 we have:

E —19	1870 Oct. 16.9	Schönfeld's II Cat.	O—C = $+4^{d}.1$
—12	1874 Sep. 9	" *A.N.* 2066	+4.1
— 3	1879 Sep. 17.0	Schmidt *A.N.* 2297	+8.4
— 1	1880 Oct. 20.0	" *A.N.* 2367	+0.8
+ 4	1883 July 31	" *A.N.* 2577	+1.7
+17	1890 Oct. 19	See above	+7.6

There are three more, but incompletely determined, maxima mentioned by Schmidt in the *A.N.* (nos. 2420, 2491, 2577) which have not been considered here, nor have the minima been taken into account.

8230. *S Aquarii.*

Few observations of this star seem to have been published, probably owing to its large southern declination.

A maximum was obtained here in 1889 from 21 observations (see this *Journal*, vol. IX, p. 157), and another in 1890 from 17 observations extending from July 11 to Oct. 3.

If determined from the single light-curves, the *maxima* occurred on the following days:

E 29, *Max.* 1889 Nov. 2, O—C = +19 days
E 30, *Max.* 1890 Aug. 6, O—C = +17 days

as referred to the elements in Prof. Schönfeld's Catalogue:

Max. 1867 Aug. 8 + 279.4 *E*.

The two light-curves appeared so peculiar in their shape, and still so similar to each other, that the construction of a mean-curve seemed to promise greater accuracy. The 38 available observations were thus combined into one series by subtracting 280 days from all the dates of the latest maximum, and then collected into 16 means or normal points. A regular curve drawn between these points, so as to leave about the same number of points on either side, gave the following *mean light-scale*:

Days	Steps	Days	Steps
—40	35.0	+12	10.2
—36	32.0	+16	10.7
—32	28.4	+20	12.5
—28	24.0	+24	14.9
—24	19.0	+28	18.0
—20	14.8	+32	21.0
—16	12.7	+36	23.9
—12	11.7	+40	26.3
— 8	11.1	+44	28.4
— 4	10.8	+48	30.2
0	10.5	+52	31.8
+ 4	10.3	+56	33.1
+ 8	10.2		

The reduction of this scale to the SDM. *magnitudes* is effected by the following table:

Steps	Mag.	Steps	Mag.
9	8.30	23	8.99
11	8.40	25	9.09
13	8.50	27	9.18
15	8.60	29	9.28
17	8.70	31	9.38
19	8.80	33	9.48
21	8.89	35	9.58

The peculiarity of the light-scale consists in the fact that the maximum, as determined by POGSON's curve, falls about nine days earlier than the greatest brightness of the star. The curve is almost flat between the days −16 and +16, but has its highest point at +9.

In this case, therefore, what is meant by the maximum, has to be exactly defined. The maxima here given have all been determined by POGSON's curve. If the highest point of the light-curve were taken, the residuals O—C would be still larger, viz.: +28 and +26.

The two maxima were then (graphically) redetermined by means of the mean light-curve, as follows:

E 29, *Max.* 1889 Oct. 31.5, O—C = +20 days, *mag.* 8.1,
E 30, *Max.* 1890 Aug. 7.9, O—C = +19 days, *mag.* 8.6.

The large residuals O—C confirm the remarks of ARGELANDER (*Beobachtungen u. Rechnungen*, etc., p. 84) with respect to irregularities in the period, and Prof SCHÖNFELD's opinion (II Catal.) that the period seems to be larger than given in his catalogue. His elements, from which those of Mr. CHANDLER differ very little, were derived from four maxima (1859-1873), in addition to which we now have three more, namely one in 1874 July 12, mag. 8.0 (*A.N.* 2065), by Prof. SCHÖNFELD, and the two of 1889 and 1890.

Georgetown College Observatory, 1891 *Mar.* 19.

ON THE RIGOROUS COMPUTATION OF DIFFERENTIAL REFRACTION.

BY S. C. CHANDLER.

When the distance of stars, measured with the heliometer or on photographic plates, is very large, or when they are near the pole or the horizon, the ordinary formulas for differential refraction entail errors which, though slight, become important in stellar parallaxes and other delicate investigations.

The attempt to deduce purely differential formulas which are free from defect in such cases, leads to complicated expressions, very troublesome in their practical application without the preparation of elaborate special tables. The simplest way to avoid this and attain the desired precision appears to be, to compute for each star,

$$\Delta\alpha = kn \operatorname{cosec}(\delta+N)\sec\delta \qquad \Delta\delta = k\cot(\delta+N)$$

Then, using the mean of the position-angles at the two stars and the mean true declination, the differential refraction in distance and position-angle may be found from the equations following.

$$(1)\qquad \begin{aligned} g\sin G &= (\Delta\alpha - \Delta\alpha')\cos\delta_0 \\ g\cos G &= (\Delta\delta - \Delta\delta') \\ h &= \tfrac{1}{4}(\Delta\delta + \Delta\delta')\tan\delta_0 \sin 2p \sin 1'' \end{aligned}$$

$$(2)\qquad \begin{aligned} \sigma - s &= g\cos(G-p) & &+ sh\tan p \\ \pi - p &= g\sin(G-p)\frac{1}{s\sin 1''} & &+ h\operatorname{cosec} 1'' \end{aligned}$$

When $\sigma - s$ and $\pi - p$ are very large we can apply the following additional corrections

$$(3)\qquad \begin{aligned} \Delta(\sigma - s) &= fsh\tan p \\ \Delta(\pi - p) &= fh\operatorname{cosec} 1'' - \frac{\sigma - s}{s}(\pi - p) \end{aligned}$$

where $$f = h\sec p\operatorname{cosec} p$$

but these terms will in general be less than 0″.01, and very small even in the most extreme cases.

If it is desired to employ the true, instead of the apparent distances and position-angles in the computation, substitute σ and π for s and p, in the second members of (1) and (2), and instead of (3) use

$$\begin{aligned} \Delta(\sigma - s) &= f\sigma h\tan\pi \\ \Delta(\pi - p) &= fh\operatorname{cosec} 1'' + \frac{\sigma - s}{\sigma}(\pi - p) \end{aligned} \qquad (4)$$

where $$f = h\sec\pi\operatorname{cosec}\pi - \frac{\sigma - s}{\sigma}$$

I will not consume space in giving the derivation, or illustrating the use, of these formulas. While on this subject, however, it may be useful to note some corrections of the text-books.

Eliminating g and G from (1) and (2), we get

$$(\Delta\alpha - \Delta\alpha')\sin p\cos\delta_0 + (\Delta\delta - \Delta\delta')\cos p = (\sigma - s) - sh\tan p$$
$$(\Delta\alpha - \Delta\alpha')\cos p\cos\delta_0 - (\Delta\delta - \Delta\delta')\sin p = s(\sigma - p)\sin 1'' - sh$$

and from these,

$$\begin{aligned} \Delta\alpha - d\alpha' = \big[(\sigma - s)\sin p + s(\pi - p)\sin 1''\cos p \\ - sh(\tan p\sin p + \cos p)\big]\sec\delta_0 \end{aligned}$$
$$\Delta\alpha - d\delta' = (\sigma - s)\cos p - s(\pi - p)\sin 1''\sin p$$

Substituting the value of h from (1), writing

$$\tfrac{1}{2}(\Delta\delta + \Delta\delta') = \kappa\tan\zeta\cos q,$$

and introducing the values of $\sigma - s$ and $\pi - p$ by BESSEL's formulas, we get CHAUVENET's equations (351), II, p. 178, except that the term in the right-ascension

$-\tan\zeta\sin q\tan\delta_0\cos p$, becomes $-\tan\zeta\tan\delta\sin(p+q)$

Similarly we must correct the first of equation (351*) by inserting in the brackets the term $-\tan u\cot q\sin p$. The error of CHAUVENET's demonstration lies in the first equation of section 298, where, in comparing the relations of the true and apparent coordinates he should have taken.

$$\Delta(\alpha' - \alpha) = \sigma\sin\pi\sec\delta_0 - s\sin p\sec(\delta + \tfrac{1}{2}(\Delta\delta + \Delta\delta'))$$

the development of which would have led to the correct form of (351) and (351*) above given. The effect of the error is small near the equator, but increases rapidly with the declination, the erroneous term becoming in fact the principal one for high declinations.

A similar error pervades the demonstrations of the differential-refraction formulas in Brünnow's Astronomy, a fact to which I have adverted in another place.

There is reason to believe that an error of another sort is frequently committed. It is a common practice, in observing a comet or asteroid, to determine the zero of position by first allowing the comparison-star to run along the transverse thread; but in such a case the refraction-formula to be used in right-ascension should be

$$\Delta(\alpha'-\alpha) = 2\kappa(\delta'-\delta)\tan^2\zeta\cos q\sin q$$

instead of the first equation of section 299 of Chauvenet; or, if the position-angle is measured, its correction should be

$$\pi - p = \kappa \operatorname{cosec} 1'' \tan^2\zeta[\cos^2 p \sin 2q - \tfrac{1}{2}\sin 2p\cos 2q]$$

instead of the second of Eq. (349). The formulas of the text-books can be correctly used only when the true, and not the apparent, zero has been determined.

In the formula (1) for position-angle, p. 175 of the last number of the *Journal*, the factor $\frac{1}{2}$ was included by a slip of the pen, and should be omitted. The second of (2) requires corresponding modification. With reference to the use of these formulas, it may be added that (1) will always be sufficiently accurate wherever the method can be employed with advantage at all. When the terms requiring the use of (2) become sensible, it will be more economical to abandon the use of the coordinates of the center of the plate.

Cambridge, 1891 *March* 12.

OBSERVED MAXIMA AND MINIMA OF VARIABLE STARS, 1890–1891,

BY PAUL S. YENDELL.

U Orionis.

Twenty-four observations of *U Orionis*, from 1890 December 24 to 1891 February 11, indicate that the star passed a maximum on 1891 January 22: the light-changes showed the usual characteristics, of a rather rapid increase, a considerable period of stationary maximum light, and a slow decrease. The greatest observed light was by estimation, $6^M.8$.

R Scuti.

R Scuti was observed forty-four times between 1890 June 15 and November 6. When first observed, it appears to have been at or near a maximum, being = the star 6 *Scuti*, or $4^M.5$; from this time it decreased steadily till August 9, when a minimum was passed of 6.6 magnitude; another maximum of $5^M.2$ occurred about September 30, and when last observed, the star was apparently at, or just past, a minimum of equal light with that of August 9.

S Sagittae.

S was observed seventy-five times during the season, and from the series of observations, eleven maxima and eight minima have been deduced, as follows:

Maxima	d	w	Minima	d	w
1890 May	19.1	3	1890 June	9.2	3
June	13.88	3		18.4	4
July	7.25	3		27.3	3
	16.23	4	July	12.5	2
	24.62	3		21.0	4
Aug.	2.9	2	Aug.	5.5	2
	18.14	1		15.4	3
Sept.	4.47	4	Oct.	12.4	3
	21.9	3			
	29.8	2			
Oct.	15.87	3			

Dorchester, Mass., 1891 *March* 13.

T Vulpeculae.

This star was observed from 1890 May 17 to December 7, the observations numbering in all seventy-one; the following maxima and minima were deduced from these by the use of a mean light-curve:

Maxima	d	w	Minima	d	w
1890 May	15.08	1	1890 June	9.41	1
	20.01	1		18.53	3
June	10.95	1	July	6.69	2
	15.74	2		11.30	1
	20.89	1		14.38	1
	23.89	1	Aug.	2.36	1
	29.17	2		5.95	2
July	3.91	2		11.38	3
	8.32	2		15.38	1
	16.88	3		24.34	1
	21.15	3	Sept.	2.33	1
	25.27	1		18.83	1
Aug.	3.79	2	Oct.	1.30	1
	13.15	1		15.30	1
	16.52	2		28.31	1
Sept.	7.66	2	Nov.	17.14	1
	20 91	2			
	29.70	2			
Oct.	9.87	1			
	13.70	1			
	22.40	2			
	31.58	2			
Nov.	4.35	4			
	13.63	2			
	22.73	1			
Dec.	1.82	1			
	5.80	2			

EPHEMERIS OF VARIABLES OF THE *ALGOL*-TYPE.

Approximate Greenwich M.T., 1891.

	April			April			May			May			June	
	d	h		d	h		d			d				
U Cephei	8	14	*Y* Cygni	24	11	*U* Ophiuchi	12	19	*U* Coronae	30	19	*U* Cephei	17	9
S Cancri	9	1	δ Librae	25	15	*U* Coronae	13	12	*R* Can. Maj.	31	8	*Y* Cygni	17	10
Y Cygni	9	12	*U* Ophiuchi	26	20	*U* Cephei	13	12				*U* Cephei	17	20
U Ophiuchi	10	22	*R* Can. Maj.	27	6	*R* Can. Maj.	14	7		June		*U* Ophiuchi	18	16
R Can. Maj.	11	9	*Y* Cygni	27	11	*Y* Cygni	15	11	*R* Can. Maj.	1	12	*Y* Cygni	18	22
δ Librae	11	16	*U* Ophiuchi	27	17	*R* Can. Maj.	15	11	*U* Cephei	2	10	*U* Ophiuchi	19	13
U Ophiuchi	11	18	*S* Cancri	28	0	δ Librae	16	14	*Y* Cygni	2	10	*Y* Cygni	20	9
U Coronae	12	11	*R* Can. Maj.	28	10	*R* Can. Maj.	16	14	*U* Ophiuchi	2	18	δ Librae	20	12
Y Cygni	12	12	*U* Cephei	28	13	*S* Cancri	16	24	*U* Ophiuchi	3	14	*U* Coronae	20	12
R Can. Maj.	12	12	*R* Can. Maj.	29	13	*U* Ophiuchi	17	20	*S* Cancri	4	23	*Y* Cygni	21	21
U Ophiuchi	12	14	*U* Coronae	29	17	*Y* Cygni	18	10	*Y* Cygni	5	10	*U* Cephei	22	9
U Cephei	13	14	*Y* Cygni	30	11	*U* Cephei	18	12	δ Librae	6	13	*Y* Cygni	23	9
R Can. Maj.	13	15				*U* Ophiuchi	18	16	*U* Coronae	6	16	*U* Cephei	23	17
Y Cygni	15	11		May		*U* Coronae	20	10	*U* Cephei	7	10	*S* Cancri	23	22
U Coronae	15	22	*U* Ophiuchi	1	21	*Y* Cygni	21	10	*U* Ophiuchi	7	19	*U* Ophiuchi	24	15
U Ophiuchi	16	19	δ Librae	2	15	*U* Ophiuchi	22	21	*Y* Cygni	8	10	*Y* Cygni	24	21
U Ophiuchi	17	15	*U* Ophiuchi	2	17	*R* Can. Maj.	23	9	*U* Ophiuchi	8	15	*Y* Cygni	26	9
Y Cygni	18	11	*Y* Cygni	3	11	*U* Cephei	23	11	*Y* Cygni	9	22	*U* Cephei	27	9
S Cancri	18	13	*U* Cephei	3	13	δ Librae	23	14	*Y* Cygni	11	10	*U* Coronae	27	10
U Cephei	18	14	*R* Can. Maj.	5	5	*U* Ophiuchi	23	17	*U* Cephei	12	10	δ Librae	27	12
δ Librae	18	16	*R* Can. Maj.	6	9	*Y* Cygni	24	10	*U* Ophiuchi	12	20	*Y* Cygni	27	21
R Can. Maj.	19	8	*Y* Cygni	6	11	*R* Can. Maj.	24	13	*Y* Cygni	12	21	*U* Ophiuchi	28	18
R Can. Maj.	20	11	*U* Coronae	6	15	*S* Cancri	26	11	δ Librae	13	12	*Y* Cygni	29	9
Y Cygni	21	11	*S* Cancri	7	12	*Y* Cygni	27	10	*U* Coronae	13	14	*U* Ophiuchi	29	14
R Can. Maj.	21	14	*R* Can. Maj.	7	12	*U* Ophiuchi	27	21	*U* Ophiuchi	13	16	*Y* Cygni	30	21
U Ophiuchi	21	20	*U* Cephei	8	12	*U* Cephei	28	11	*Y* Cygni	14	10			
U Ophiuchi	22	16	*Y* Cygni	9	11	*U* Ophiuchi	28	17	*S* Cancri	14	10			
U Coronae	22	19	δ Librae	9	15	*Y* Cygni	30	10	*U* Ophiuchi	14	12			
U Cancri	23	13	*Y* Cygni	12	11	δ Librae	30	13	*Y* Cygni	15	22			

NOTE ON ZENITH-TELESCOPE STAR-CORRECTIONS.

BY HAROLD JACOBY.

Since my note on the above subject appeared in *A.J.* 238, my attention has been called to a paper by Prof. SAFFORD (*Proc. Am. Ac. of Arts and Sc.*, 1875, vol. XI, p. 167), where it is shown that the reduction I have called $\Delta\phi$ can also be computed by means of the Besselian constants. It is clear that we may write:

$$\Delta\phi = \tau\nu_0 + \tfrac{1}{2}(a'_1+a'_2)\,A + \tfrac{1}{2}(b'_1+b'_2)\,B + \tfrac{1}{2}(c'_1+c'_2)\,C + \tfrac{1}{2}(d'_1+d'_2)\,D.$$

and this equation is given by Prof. SAFFORD. The same form was also used in the reduction of some of the recent German observations. I regret that at the time of writing I was not aware that I had been partly anticipated. I think, however, that under some circumstances the formulas I have given will be found very convenient.

Columbia College, New York, 1891 *March* 30.

COMET *a* 1891.

Professor HOLDEN telegraphed, March 30, the discovery of a comet by BARNARD:

1891 March 29.695 Gr. M.T. $\alpha = 1^h\ 0^m\ 8^s$, $\delta = +41°\ 18'$.

It is described as of about 10^M, less than 1′ in diameter, with a tolerably well-defined nucleus, and a tail less than 30′ long. Daily motion, 1° southward.

On March 31, a dispatch from Kiel announced the discovery at Bristol (probably by Mr. DENNING) of a bright comet in the position: —

March 30.417 Gr. M.T. $\alpha = 0^h\ 56^m\ 0^s$, $\delta = +43°\ 0'$. Daily motion, 1° 10′ southward.

These two observations probably refer to the same object.

A telegram from Lick Observatory, received April 4, gives an orbit computed by Prof. Schaeberle: —

Elements.

T = 1871 April 27.67 Greenw. M.T.

$\omega = 184° \ 31'$

$\Omega = 194 \ \ 24$

$i = 120 \ \ 30$

$q = 0.3644$

Ephemeris.

Gr. Midnight	App. α	App. δ	Brightness
	h m s	° ′	
1891 April 2	1 11 28	+40 48	1.14
6	21 16	36 35	
10	29 23	32 17	
14	1 36 21	+27 48	2.13

NEW ASTEROID.

An asteroid was discovered by Borrelly at Marseilles, in the position: —

1891 March 31.4136 Gr. M.T. $\alpha = 12^h \ 24^m \ 49^s.3$, $\delta = -1° \ 55' \ 32''$. Daily motion, —40′ in α, and 5′ northward.

This would appear to be no. 309. The magnitude is not telegraphed.

NEW ASTRONOMICAL WORK.

Catalogue of the Crawford Library of the Royal Observatory, Edinburgh. Edinb. 1890, pp. 497. 4to.

A luxuriously printed volume, containing a full catalogue of the contents of the library of Dunecht Observatory, presented in 1888 to the Royal Observatory of Edinburgh by the Earl of Crawford — prepared by the present Astronomer Royal for Scotland, Mr. Copeland.

The original nucleus of this library was formed by that of the late Mr. Babbage, and this was enlarged by the acquisition of other works in astronomy, mathematics and physics, — some of them being extremely rare. To these have been added numerous publications of more recent years, so that the present catalogue forms a valuable contribution to astronomical bibliography. The number of rare and valuable books, whose titles attract the eye, even upon a superficial glance through the pages, is great.

The general arrangement is alphabetic, according to the names of authors, but special headings have been introduced for nearly twenty subjects, to facilitate reference. Such, for instance, are Academies, Comets, Ephemerides, Observatories, Transits of *Mercury* and of *Venus*, etc. The number of treatises on Comets, both general and special, is notably large; and these have evidently been classified with extreme care.

Throughout the catalogue, minute attention has been paid to the description of the several works. The titles are reproduced in full, and, in some cases, with additional details. The full names of authors are given, whenever accessible; and not merely the place and year of publication, the size, the number of pages, but also the number of plates and maps in each volume, as well as that of the volumes or part belonging to each work, although all of them may not be contained in the library.

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CORRIGENDA.

No. 238, p. 170, col. 2, line 5 in numerator *for* $C - C_2$ *put* $C_1 - C_2$.

p. 172, col. 1, lines 6 and 7 from below, the whole of the formula after $\frac{1}{4}h$ is to be inclosed in parentheses.

p. 172, col. 2, line 6 from below, after the word "positive,," *add* "in the Northern hemisphere."

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ON THE RECTIFICATION OF CHRONOLOGY BY MEANS OF ANCIENT ECLIPSES,

BY JOHN N. STOCKWELL.

1. In Nos. 220-1 of this *Journal* I have employed a number of well-authenticated ancient eclipses of the sun for the purpose of correcting the elements of the moon's motion; and have then used these corrected elements in the discussion of the traditions concerning other eclipses, and have found a remarkable and satisfactory correspondence between the calculated and recorded phenomena. This agreement between calculation and observation, extending over a period of more than three thousand years, seems to justify the belief that we may now place implicit confidence in the general correctness of the theory of the lunar motions; and that we may safely employ this corrected theory in the discussion of lunar phenomena during any period of time. I now propose to employ this theory in the discussion of some historical questions in which the place of the moon in the heavens enters as an important element.

The application of the theory of eclipses to the improvement of chronology is not new; it has been applied with more or less success ever since the termination of the "Dark Ages" in Europe; a period of nearly five hundred years. But its successful application requires the simultaneous existence of the two following conditions: namely, *First*, the theory of eclipses must be in such a state of perfection that any eclipse occurring within the historical period may be accurately calculated; and *secondly*, the narratives concerning any eclipse must be given with sufficient fullness and precision to enable us to identify an observed eclipse with a calculated eclipse for the same date. As already observed, we have reason to believe that we are now in possession of the first required condition; but unfortunately, the second condition cannot be said to exist except in comparatively few instances. It is, of course, easy to understand why the narratives concerning celestial phenomena occurring in remote ages, before predictions were possible, should sometimes be extremely meagre or wholly wanting. The meteorological conditions of our planet are such that whole continents are often overcast with dense clouds for days and weeks together. And if, during one of these periods of obscuration, a total eclipse of either the sun or moon were to take place, it is evident that there would be no traditions concerning such an event. It is therefore scarcely to be wondered that the narratives concerning events which happened in a remote and uncritical age should often be wanting in some element of usefulness; although they seem in many cases to be unnecessarily defective.

But it sometimes happens that a succession of events occurs in such a manner that we may determine their chronology even in the case where the lunar tables are considerably erroneous, and fail to represent any one of the events as described by the historian. A notable example of this character occurs in the writings of THUCYDIDES. That historian relates that an eclipse of the sun occurred at Athens during the summer of the first year of the Peloponnesian war, which was so nearly total that some of the stars were visible. He also tells us that there was another eclipse of the sun at the very beginning of the summer of the eighth year of the war, and an eclipse of the moon sometime during the nineteenth year of the war. Now, although astronomers have never been able to find an eclipse that would accord with the description of the first one above mentioned, as to magnitude, they have found that eclipses occurred in the years 431, 424 and 413 B.C., which were visible in Greece and which accorded sufficiently well with the historical traditions concerning them, as to justify the belief that the first year of that memorable war was 431 B.C. And hence that date has been universally adopted for the beginning of that war, because there are no other years near that period of time, in which eclipses visible in Greece occurred in that order. But I have shown in a former number of this *Journal*, that my corrected elements of the moon's motion give the first two eclipses recorded by THUCYDIDES, magnitudes which accord well with the description of the historian. But as a further confirmation of the correctness of my views on this subject, I have since computed the eclipse of the moon which was observed at Syracuse in Sicily, on the evening of August 27, 413 B.C.; and which is mentioned by THUCYDIDES in book VII, chapter 50, of his history. I find that the eclipse began at 9ʰ 6ᵐ, was total at 10ʰ 22ᵐ, ceased to be total at 11ʰ 12ᵐ, and ended at 0ʰ 28ᵐ the next morning. These numbers denote mean time at Syracuse. The magnitude of the eclipse was 13.26 digits on the moon's southern limb. The three eclipses mentioned by Thucydides are therefore completely identified; and there is probably no event of ancient times whose date is more accurately or firmly established than that of the Peloponnesian war.

Again, Thucydides informs us that the Persian war under Xerxes preceded the beginning of the Peloponnesian war by fifty years. It has, however, been claimed that Thucydides was merely speaking in round numbers; and that the true interval might be a year or two more or less than that number. But it seems to me that such an interpretation is taking unwarranted license with a historian so critically precise as Thucydides. For Thucydides specifies a particular event of the war; namely, "the retreat of Xerxes as preceding this war by about fifty years;" and according to my former computation there was a small eclipse of the sun at Sardis in the spring of 481 B.C., agreeing with the statement of Aristides concerning the time when Xerxes was in the region of the Hellespont at the beginning of that memorable war. This would make the number of years exact; and Thucydides could not have been more precise in his statement unless he had given the interval in years, months and days. It therefore seems to me that we are fully justified in dating the Persian war as 481 B.C., which is one year earlier than the date usually assigned to that event.

Moreover, Herodotus informs us that the Persians found the Greeks celebrating the Olympic games on their arrival in Greece: and as these festivals occurred only at intervals of four years, they must have then been celebrating the 75th Olympiad. The first Olympic festival must therefore have taken place in the year 777 B.C. instead of 776 B.C., as usually given; and this agrees with the statement of the chronologer Sextus Julius Africanus, who tells us that the Olympic festivals were celebrated in the bissextile years of the Julian calendar.

2. I shall now consider the circumstances connected with the death of Augustus Caesar. It is well known that the death of Augustus was followed by a formidable sedition of three Roman Legions in the province of Pannonia; and that this sedition was suppressed mainly through the influence of an eclipse of the moon upon the superstitious Roman soldiery. The circumstances attending the sedition and its suppression are given in the first book of the "Annals" of Tacitus; and on account of the great importance of this event in chronology, I here reproduce nearly the whole of his account of the eclipse and its attendant incidents. It is as follows:

> *Annals*, I, 28. "The following night had a threatening aspect, and seemed likely to give birth to some impious deed; it was made to pass off tranquilly by a mere accident. The moon, in the midst of a clear sky, became suddenly eclipsed: the soldiers, who were ignorant of the cause, took this for an omen referring to their present adventures; to their own labors they compared the eclipse of the planet, and prophesied, 'that, if to the distressed goddess should be restored her wonted brightness and splendor, equally successful would be the issue of these their struggles;' hence they made a loud noise, by ringing upon brazen metal, and by blowing trumpets and cornets; as she appeared brighter or darker, they exulted or lamented; but when gathering clouds had obstructed their sight, and it was believed that she was now buried in darkness, then (for minds once dismayed are prone to superstition) they bewailed 'their own eternal sufferings thus portended, and that the gods viewed their daring deeds with aversion.' Drusus, who thought it behoved him to improve this turn in their minds and to convert to the ends of wisdom what chance had presented, ordered certain persons to go around from tent to tent. For this purpose, he summoned the centurion Clemens, and whoever else were for their good qualities acceptable to the multitude. These insinuated themselves everywhere, and mixed with those who kept the night watch, the pickets, and sentinels at the gates, cheering their hopes or alarming their fears. . . . These reasonings alarmed them, and filled them with mutual jealousies; they separated the younger soldiers from the veterans, and one legion from another; then by degrees, returned the love of duty and obedience. They relinquished the guard of the gates; and the standards, which in the beginning of the tumult they had thrown together, they now restored each to its distinct station. Drusus, as soon as it was day, summoned an assembly of the soldiers. . . ."

Augustus is said to have died on the nineteenth of the August preceding the date of the eclipse which terminated the sedition; and was immediately succeeded by Tiberius: and the eclipse itself is generally supposed to have occurred on the twenty-seventh of September in the year 14 A.D. The question of the correct identification of the preceding eclipse is therefore an important one.

Had the historian stated the time of night at which the eclipse occurred, it would have been an important element in the question of its identification. But since he has omitted to state the time of its occurrence, we are obliged to draw an inference as to that fact from the sequence of events which took place during its continuance and after its termination; and it seems very obvious, and almost certain, that the eclipse occurred early in the evening rather than late in the morning; for the historian tells us that on the return of day Drusus summoned an assembly of the soldiers.

Now there was a total eclipse of the moon on the morning of September 27 in the year 14 A.D.; but it took place at so late an hour that it seems very improbable that it could be the one referred to by the historian. According to my computation it commenced at $4^h\ 42^m$, was total at $5^h\ 40^m$, ceased to be total at $7^h\ 19^m$, and ended at $8^h\ 17^m$ mean time in Pannonia. The middle of the eclipse therefore took place at $6^h\ 30^m$; but the sun rose at $5^h\ 42^m$; and since the moon had not quite reached its opposition with the sun, it must have set before the sun rose. Moreover, twilight began at that date, in Pannonia, at $4^h\ 20^m$ in the morning, which is 22 minutes before the beginning of the eclipse; and day itself had returned before the eclipse became total. The whole of the eclipse in Pannonia therefore took place during the morning twilight, and could not, it seems to me, have inspired a feeling of dread in the seditious soldiery. It therefore seems impossible that the eclipse of A.D. 14 could be the one described by the historian.

On the other hand there was an eclipse of the moon on October 7, A.D. 13, which seems to correspond well with the circumstances narrated by the historian. According to my computation it commenced at 7^h 35^m and ended at 9^h 33^m, Pannonia mean time. Its duration was therefore nearly two hours; but it was only partially eclipsed, its greatest magnitude being only about $3\frac{1}{4}$ digits on the moon's northern limb. The smallness of this eclipse has been urged by historians as an argument against its being the one that occurred during the sedition; it being claimed that an eclipse of less than one-third of the moon's disk would not be sufficient to inspire a feeling of dread in the seditious soldiers. But I imagine that it was the gradual darkening of the moon's face, by the earth's shadow, in conjunction with the clouds spoken of by TACITUS, rather than the greatness of the obscuration, that caused the various phases of astonishment, vague fear and superstitious dread of some impending calamity; and stimulated the wavering sense of duty and loyalty in the minds of the seditious soldiery. For since the cause of the eclipse was unknown to the multitude, it could readily be attributed to the displeasure of some offended deity; and when at length the shadow had begun to pass away, it might also be an assurance that the same deity had been reconciled by returning loyalty and obedience. Besides, I am not certain that an obscuration of one-third of the moon's face during the darkness of night would be more awe-inspiring than a total obscuration a few minutes before sunrise.

There is also another argument in favor of the eclipse of A.D. 13 being the one referred to by the historian; and that is, the greater interval of time between the death of AUGUSTUS and the eclipse in question. For if it took place in A.D. 14, there would have been an interval of only thirty-eight days between the two events; but if it occurred in A.D. 13, there would have been an interval of forty-nine days. And it is claimed by some historians that the events which are recorded as having taken place between the death of AUGUSTUS, and the eclipse could not well have been performed in the shorter interval; but the argument is not astronomical, and need not be elaborated in this place.

It therefore seems highly probable that the death of AUGUSTUS took place in the year A.D. 13, instead of A.D. 14, as has been generally supposed.

3. As a second example in which eclipses serve to throw strong light upon chronological questions, we may observe that PLINY the younger, speaks of an eclipse of the sun and another of the moon within fifteen days of each other, during the third year of the reign of VESPASIAN. According to the commentators this has been assigned to the year 72 A.D. Now it is no uncommon occurrence for eclipses to happen in the order mentioned. In fact, in the year 72 A.D., there were four sets of such eclipses, which took place as follows: The sun was eclipsed Feb. 7, the moon, Feb. 22, and the sun again on March 8; also the sun was eclipsed on Aug. 2, the moon on Aug. 17, and the sun again on Sept. 1. But unfortunately for the hypothesis, none of these eclipses were visible in Italy or Europe. In the year 71 A.D., however, there was an eclipse of the moon on March 4, and one of the sun on March 20, both of which were visible at Rome. For the moon was eclipsed five and one-fourth digits at 9^h 23^m at Rome on the evening of March 4; and the sun was almost totally eclipsed at 11^h 0^m on the morning of March 20. The year 71 A.D. was therefore the third of VESPASIAN's reign; and since it commenced on July 1, three full years would have been completed on July 1, A.D. 71. It therefore follows that his reign commenced July 1, A.D. 68, instead of 69; and since, according to JOSEPHUS, the city of Jerusalem was taken in the second year of VESPASIAN, on the eighth day of the month Gorpiaeus (Elul), it follows that it was taken and destroyed in the summer of 69 A.D. instead of 70 A.D., as stated by modern historians. The three eclipses which I have already discussed, strongly indicate that the dates of events which transpired during the early years of the empire should be carried backward by one year. But there is one other event which throws additional light on the subject.

4. The author of the history of CAESAR's War in Spain, states that on the third day before the nones of March, or, according to our reckoning, the fifth of March, occurred the battle of Soricia; that on the same day POMPEY removed his camp to an olive grove over against Hispalis, and was followed by CAESAR; but that before CAESAR had commenced his march the moon had risen about midnight. The date assigned by historians for the war in Spain is 45 B.C.; but in 45 B.C. there was a new moon on March 1, and it would be less than five days old on March 5; it could not possibly have risen about midnight at that date. But in the year 46 B.C. there was a new moon on March 12; and on March 5 it would have been about the last quarter, and consequently would have risen about midnight. The Spanish war therefore occurred in 46 B.C. instead of 45 B.C.; and the four astronomical events recorded by historians prove conclusively that the early dates of the Roman Empire should be placed one year earlier in chronology.

5. Again, JOSEPHUS informs us that there was an eclipse of the moon, visible at Jerusalem a short time before the death of HEROD the Great; and on account of the importance of this eclipse in Biblical history and the early history of Christianity I have computed all the eclipses of the moon that were visible at Jerusalem during the first five years preceding the Christian Era. They are as follows:

The first occurred B.C. 5, March 23, commencing at 7^h 26^m, and ending at 11^h 8^m in the evening. The middle of the eclipse occurred at 9^h 17^m, and it was totally eclipsed during one hour and forty minutes.

The second eclipse occurred B.C. 5, September 15; commencing at $9^h\ 40^m$ and ending at $1^h\ 14^m$ in the morning of September 16. The middle of the eclipse was at $11^h\ 27^m$ in the evening; and it was totally eclipsed during one hour and thirty-six minutes.

The third eclipse occurred B.C. 4, March 13; commencing at $1^h\ 45^m$ and ending at $4^h\ 10^m$ in the morning. The middle of the eclipse was at $2^h\ 58^m$; but the eclipse was only partial, having a magnitude of a little more than *four* digits, on the moon's northern limb.

The fourth eclipse occurred B.C. 1, January 10, commencing at $0^h\ 31^m$ and ending at $4^h\ 2^m$ in the morning. The middle of the eclipse was at $2^h\ 17^m$, and it was totally eclipsed during one hour and thirty-six minutes.

The fifth eclipse occurred B.C. 1, January 29; commencing at $4^h\ 50^m$ and ending at $7^h\ 16^m$ in the evening. The middle of the eclipse was at $6^h\ 3^m$; and it was only partial, having a magnitude of a little more than *six* digits on the moon's northern limb. These are the only eclipses that were visible at Jerusalem during the first five years preceding the Christian Era. The hours and minutes given are in local mean time at Jerusalem.

Some difficulty has been found in reconciling the historical statements of Josephus in regard to the death of Herod the *Great*, with the statements of Matthew and Luke concerning the same event, in the New Testament. For example, Josephus tells us that Jerusalem was taken by Pompey during the consulship of Cicero and Antony, which is supposed to have been in the year 63 B.C.; and that it was captured again by Herod and Sosius twenty-seven years later, which would be in 36 B.C.; and also that Herod was king of the Jews thirty-four years after the taking of Jerusalem, when he died. Therefore according to Josephus, Herod died in the year 2 B.C. Now Matthew states that Christ was born while Herod was king of the Jews; therefore Christ was born before 2 B.C. Luke informs us that Christ "began to be about thirty years old" during the fifteenth year of the reign of Tiberius. We have already found that the reign of Tiberius commenced in August A.D. 13; and consequently the fifteenth year of his reign would commence in August A.D. 27. Luke's statement is too indefinite to predicate an argument upon; but if we assume that Christ was thirty years old at the commencement of Tiberius' reign it would follow that he was born as early as August in the year 4 B.C.

It has very generally been supposed that the eclipse of the moon which preceded the death of Herod took place March 13, B.C. 4. But his death occurred a short time before the Jewish feast of the "Passover;" which must have been celebrated at the next full moon, which occurred on April 11, only a month later than the eclipse itself. If this is the correct eclipse, Herod must have died early in the year B.C. 4, whereas we have seen that according to other arguments, he died in B.C. 2. But historians have maintained with a good deal of plausibility that the interval of time between that eclipse and the Passover of the same year was much too short for all the events narrated by Josephus to have taken place; and as there was no other eclipse visible at Jerusalem until January 10, B.C. 1, it has been a matter of great difficulty to find an eclipse that will satisfy all the historical conditions. Messrs. Hind and Johnson have concluded that the eclipse of January 10, B.C. 1, best satisfies the required conditions; but in forming this conclusion, it seems to me they have ignored all the historical statements concerning the events as related by Josephus, who is the principal authority in the whole matter. For Josephus very plainly states that Herod captured the city twenty-seven years after Pompey, and reigned thirty-four years, when he died. Therefore Herod died sixty-one years after the taking of Jerusalem by Pompey; and since it is generally admitted that Pompey captured Jerusalem as early as the year 63 B.C., it follows that Herod must have died as early as the year 2 B.C. Besides, the eclipse happened *before* the death of Herod; and it therefore seems certain that we cannot accept the eclipse of B.C. 1 as the correct one, without doing violence to the statements of the historian.

But Josephus also tells us that the capture of Jerusalem by Pompey was in the one hundred and seventy-ninth olympiad, and that it was captured by Herod in the one hundred and eighty-fifth olympiad. Now since an olympiad is a period of four years, there might be some doubt as to the interval between the two dates, since he has not told us the particular year of each olympiad when the events took place. But he has supplied this omission by stating that the interval was precisely twenty-seven years; and it therefore follows that it was captured by Pompey in the *first year* of the one hundred and seventy-ninth olympiad, and by Herod in the *fourth year* of the one hundred and eighty-fifth olympiad.

If we now assume that the era of the olympiads commenced in B.C. 777 — as I have already given reasons for believing — the first year of the one hundred and seventy-ninth olympiad would be the year 65 B.C.; and since Herod died sixty-one years later, he must have died in the year 4 B C. If this belief is well founded, the eclipse of September 15, B.C. 5, which occurred seven months before the Passover of B.C. 4, would satisfy all the historical circumstances connected with the event; and I do not hesitate to believe that that eclipse is really the one referred to by the historian.

6. The events already narrated nearly all occurred after the reformation of the calendar by Julius Caesar, which took place in the year 47 B.C.; and are therefore free from any uncertainty arising from the confusion of dates incident to previous Roman reckoning. But in the study of the chronology of the earlier Roman history, we are obliged, not only to identify an eclipse, but also to rectify the calen-

dar itself, to which the eclipse is referred; and that is a matter of some difficulty, because the ancient Roman calendar was left in great measure to the care and discretion of Roman officials, and was therefore subject to sudden and capricious changes. I shall therefore consider only two cases, and these will be the two eclipses which are mentioned by the historian LIVY.

The first of these was an eclipse of the sun, which occurred during the celebration of the Apollinarian games, and LIVY's account of it is as follows, XXXVII, 4:

> "At the time in which the consul set out to the war during the celebration of the Apollinarian games, on the fifth day before the ides of Quintilis (July 11), though the sky was serene, the light was obscured in the middle of the day, when the moon passed beneath the orb of the sun."

Mr. W. T. LYNN in the *Observatory* for May, 1888, designates "the fifth day before the ides of Quintilis" as June 10; and refers the eclipse to the year B.C. 190, March 14. Therefore, according to Mr. LYNN, the Roman calendar was then eighty-eight days in error. But, according to Roman law at that time, the celebration of the games commenced on the sixth of July and continued several days; so that if the eclipse to which he refers actually took place on March 14, the calendar must have been in error by one hundred and nineteen days. Now I find that there was an eclipse of the sun which was total at Rome at $8^h\ 43^m$ in the morning of March 14; but the time of year at which it occurred is so very different from that assigned by the historian, and also implies so great confusion in the calendar, that it may be considered as somewhat doubtful that the eclipse has been correctly identified. But there was another eclipse at Rome on July 17, 188 B.C.; and this has also been considered as the one referred to by LIVY. Now I find by calculation that the sun was very nearly totally (11 digits) eclipsed at Rome on July 17, at $7^h\ 14^m$ in the morning; and as this agrees well with the statement of the historian, and also implies much less confusion in the calendar at that time, it seems to me that we are justified in regarding it as the one to which the historian refers. If this inference is correct, it follows that the calendar was at that time only *six* days in error, instead of *one hundred and nineteen* days, as in the former case.

As a last example I shall consider the eclipse that occurred on the eve of the battle of Pydna. LIVY mentions that the eclipse was foretold to the Roman legions by SULPICIUS GALLUS, in order to prevent the alarm that would doubtless be inspired by its unexpected occurrence; and PLUTARCH thus relates the circumstances attending its development:

> *Aemilius Paulus*, 17, 3. "When the army had supped, and were thinking of nothing but going to rest, on a sudden, the moon, which was then full, and very high, began to be darkened, and after changing into various colors, was at length totally eclipsed."

The Romans, upon this, made a noise with brazen vessels, and held up lighted torches in the air to recover the moon's light, but the Macedonians were seized with terror.

Two dates have been assigned for this eclipse. The generally accepted date is B.C. 168; but Mr. JOHNSON considers that the more probable date was B.C. 167. I have therefore computed the two eclipses which took place in those years. In 168 B.C. there was an eclipse of the moon June 21, commencing at $6^h\ 10^m$ and ending at $9^h\ 51^m$, Pydna mean time. The middle of the eclipse was therefore at $8^h\ 0^m$, and the eclipse was total during one hour and sixteen minutes. The sun set at Pydna at that date at $7^h\ 25^m$, and there must have been considerable twilight for nearly an hour after sunset, and totality must have ceased before twilight ended. The moon therefore rose totally eclipsed; and this circumstance does not seem to accord very well with the tradition concerning it.

In the year 167 B.C. there was an eclipse of the moon June 12, commencing at $1^h\ 13^m$ and ending at $4^h\ 30^m$ in the morning. The middle of the eclipse was therefore at $2^h\ 51^m$; and it was totally eclipsed during twelve minutes. This eclipse would therefore seem to accord better with the description of the historian than the one which occurred the year before; and it therefore seems to me that it is the more probable of the two. The calendar date of the eclipse, according to LIVY, was September 3; so that the calendar was then in error by either seventy-four days, or eighty-three days, depending on the eclipse which we regard as the right one.

7. We may therefore summarize the more important events whose chronology will be changed, if my investigations are correct, as follows:

First, Jerusalem was destroyed by TITUS in the year 69 A.D. instead of 70 A.D.

Second, AUGUSTUS died in August, 13 A.D. instead of 14 A.D.

Third, The last year of confusion in the Roman calendar was 47 B.C. instead of 46 B.C.

Fourth, CAESAR's Spanish War was in the years 47 and 46 B.C.

Fifth, CAESAR was assassinated in March, 45 B.C. instead of 44 B.C.

Sixth, Jerusalem was taken by POMPEY in 65 B.C., and by HEROD in 38 B.C.

Seventh, HEROD's eclipse occurred in the year 5 B.C., September 15; and HEROD died early in the year 4 B.C.

Eighth, The Persian invasion of Greece by XERXES occurred in the year 481 B.C., instead of 480 B.C.; and

Ninth, The Era of the Olympiads commenced in July, 777 B.C. instead of 776 B.C.

It should be observed in this connection, that the B.C. dates here given are those of ordinary chronology, instead of astronomical dates, as in my former papers on this subject.

Cleveland, Ohio, 1891 *April* 2.

DISCOVERY AND OBSERVATIONS OF COMET *a* 1891,

By E. E. BARNARD.

At about 8^h March 29, while searching for comets in the northwest, with the 4-inch broken-tube comet-seeker, I discovered a small faint nebulous object, which, upon examination with the 12-inch, proved to be a comet. It was between the tenth and eleventh magnitudes, and had a faint tail, some 10′ or 15′ long, with occasionally a very faint nucleus. In the hurry to get an observation before the comet was lost in the haze, it was not possible to use the filar-micrometer, so its position was determined with a ring-micrometer. None of the objects were favorably situated with reference to the center of the ring for accurate observation.

The comet is decreasing rapidly in brightness. On April 1, it had lost at least one-third of its light at discovery.

Mt. Hamilton, 1891 *April* 6.

RING AND FILAR-MICROMETER OBSERVATIONS OF COMET *a* 1891, (*BARNARD, Mar. 29*)

MADE WITH THE 12-INCH EQUATORIAL OF THE LICK OBSERVATORY, BY E. E. BARNARD.

1891 Mt. Hamilton M.T.	*	No. Comp.	☄ — * $\Delta\alpha$	☄ — * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
d h m s			m s	m s	h m s	° ′ ″		
March 29 8 34 10*	1	6 , 6	+5 5.80	−2 47.6	1 0 9.05	+44 48 59.9	9.889	0.798
8 38 1*	2	4 , 4	+3 38.88	−1 11.9	1 0 9.87	+44 49 1.7	9.883	0.802
30 7 56 19	3	12 , 6	−0 47.12	−7 34.8	1 3 12.50	+43 48 24.7	9.799	0.713
31 7 59 10	4	6 , 4	−5 54.68	+1 45.3	1 6 17.40	+42 44 8.0	9.771	0.760
April 1 8 1 32	5	10 , 3	−1 8.98	+0 31.6	1 9 9.7	+41 41.2	9.761	0.769
2 7 50 4	6	6 , 4	+4 46.33	+0 51.5	1 11 51.36	+40 40 15 8	9.763	0.752
7 50 4	7	6 , 4	+4 32.19	. . . . .	1 11 51.16	. . . .	9.763	. . .
3 7 54 46	8	12 , 4	+1 9.63	+2 14.1	1 14 46.95	+39 35 29.3	9.751	0.762

Mean Places for 1891.0 of Comparison-Stars.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″		
1	0 55 5.58	−2.33	+44 51 53.0	−5.5	W.B. O, 1352
2	0 56 33.32	−2.33	+44 50 19.1	−5.5	W.B. O, 1382
3	1 4 1.95	−2.26	+43 56 4.6	−5.1	Compared with Paris 1427
4	1 12 14.38	−2.19	+42 42 27.5	−4.8	W.B. I, 192
5	1 10 20.8	−2.12	+41 40.8	−4.5	DM. 41° 234
6	1 7 7.08	−2.05	+40 39 28.4	−4.1	W.B. I, 71, 72
7	1 7 21.02	−2.05	+40 34 21.0	−4.1	W.B. I, 77, 78
8	1 13 19.42	−2.10	+39 33 16.8	−1.6	Lal. 2348

* Observations of March 29 with ring-micrometer.

Star 3 —Paris 1427, $\Delta\alpha = +3^m\ 1^s.43$ (6), $\Delta\delta = -5'\ 57''.0$ (2).

April 1. Comet in clouds near horizon; observation difficult. The declination somewhat uncertain.

These are, perhaps, the last observations of this comet that will be obtained here, as a spell of bad weather has set in, and the comet is getting too near the sun.

OBSERVATION OF COMET *a* 1891, (*BARNARD*)

MADE AT THE U.S. NAVAL OBSERVATORY WITH THE 9.6-INCH EQUATORIAL.

By E. FRISBY.

[Communicated by the Superintendent.]

1891 Washington M.T.	*	No. Comp.	☄ — * $\Delta\alpha$	☄ — * $\Delta\delta$	☄'s apparent α	☄'s apparent δ	log $p\Delta$ for α	log $p\Delta$ for δ
d h m s			m s	′ ″	h m s	° ′ ″		
April 8 7 43 15.1	1	8 , 2	−0 27.93	+14 18.2	1 25 24.91	+34 28 20.6	9.745	0.688

Mean Place for 1891.0 of Comparison-Star.

*	α	Red. to app. place	δ	Red. to app. place	Authority
	h m s	s	° ′ ″	″	
1	1 25 54.74	−1.90	+34 14 9.3	−6.9	Leiden Zones 238, 332

NOTE ON PHOTOGRAPHIC REFRACTIONS,

BY HAROLD JACOBY.

In connection with Mr. CHANDLER's note in *A.J.* 238 it may be well to observe that the results given are not as accurate as stated. For instance, if we assume:
$\phi = 50°$, $\delta = 60°$, $\zeta = 10°$, $p = 235°$, $q = 180°$, $s = 3600''$, the error in $\Delta\,(\sigma - s)$ of Mr. CHANDLER's accurate formula (2) is $0''.02$, while the "square of the refraction" in this instance is only $0''.000005$. Whether such errors are allowable is a matter to be determined in each particular case; but it should be remembered that they will be systematic, and may thus affect the mean derived from many photographic plates. Moreover, the quantities in question are so small, that it would probably be easy to find an empirical formula, even simpler than Mr. CHANDLER's formula, which would not give rise to very appreciable errors. Finally, it should not be forgotten that κ itself is no longer constant, if ζ be greater than 60°.

Mr. CHANDLER also refers to an "assumption that the exposures are instantaneous." Now it is clear that if the observer at the guide-telescope is careful, the image of some central star will give a dot on the plate. Every other star-image will describe a little curve, owing to varying refraction. But in measuring the plate under the microscope, we *bisect* the star-curves; which is equivalent to assuming that the length of the curve described by any star-image is proportionate to the time of exposure. This assumption neglects only quantities of the order of squares of the refraction. No terms of that order were retained in my article, as stated by Mr. CHANDLER.

Columbia College, New York, 1891 *March* 26.

THREE HUNDRED AND TENTH ASTEROID.

A telegram from Kiel, received April 8, announces the discovery of an asteroid of the thirteenth magnitude, by PALISA. The position was

1891 April 6.3995 Gr. M.T. $\alpha = 12^h\ 41^m\ 16^s.4$, $\delta = -6°\ 15'\ 54''$. Daily motion, -56^s in α, and 4′ northward.

Names have been given, as follows, to recently discovered asteroids:

296 *Phäetusa*, 297 *Cecilia*, 298 *Baptistina*, 300 *Geraldine*, 302 *Clarissa*.

ELEMENTS OF COMET *a* 1891, (*BARNARD*),

BY WILLIAM BELLAMY.

$$T = 1891 \text{ April } 27.5370 \text{ Gr. M.T.}$$

$$\left.\begin{aligned} \omega &= 178°\ 55'\ 44'' \\ \Omega &= 193\ \ 55\ \ 10 \\ i &= 120\ \ 31\ \ 23 \end{aligned}\right\} 1891.0$$

$$\log q = 9.598826$$

Middle place, $\quad \text{C—O} \quad \Delta\lambda\cos\beta \quad +1''.2$
$\qquad\qquad\qquad\qquad \Delta\beta \quad +2\ .2$

EQUATORIAL COORDINATES.

$$x = [9.987526]\ r\sin(v + \ 80°\ 41'\ 10'')$$
$$y = [9.435741]\ r\sin(v + 101\ \ 37\ \ \ \ 8\ )$$
$$z = [9.995932]\ r\sin(v + 172\ \ 36\ \ \ \ 8\ )$$

Computed from the observations at Lick, March 29; Cambridge, April 1; and Cambridge, April 9.

NEW ASTRONOMICAL WORKS.

Annalen der Sternwarte in Leiden, herausgegeben von Dr. H. G. VAN DE SANDE BAKHUYZEN, *Direktor der Sternwarte. Fünfter Band*, 1890. *Sechster Band*, 1890.

The fourth volume of the Annals of the Leiden Observatory contained the first half of the observations, made under the direction of Dr. BAKHUYZEN, in the belt from 30° to 35° declination for the great catalogue of the *Astronomische Gesellschaft*. For this work, 199 zones had been observed between 1870 Sept. 23 and 1872 May 26, and the resultant positions of 10395 stars were given, fully reduced and with all needful detail.

This fifth volume contains the results for the remainder of the stars included in the programme. They are afforded by 212 additional zones, observed between 1872 June 1, and 1876 May 30, and containing the mean positions, for 1875.0, of 9951 stars, together with the details of the observations from which these are deduced.

Thus the total number of stars, between the parallels 29° 50′ and 35° 10′ observed at Leiden for the A.G. Catalogue is 20319; and since the number of stars, in the original list for this belt was about 10250,—implying about 20500 determinations,—it is not probable that many more than 150 observations are wanting. The omitted stars are, according to Dr. BAKHUYZEN, distributed through all hours of right-ascension, and are to be observed when the essential completion of the resultant catalogue shall have shown what additional observations are requisite for reconciling any possible discordances.

The observers at the telescope, by whom the transits were registered and the pointings for declination made, were

Dr W. VALENTINER	for [illegible] stars
Dr. F. BECKER	172[illegible]
Dr H. G. v. d. S. BAKHUYZEN	" 6[illegible]
Dr. E. F. v. d. S. BAKHUYZEN	" 1818

each observer being assisted by a recorder at the [illegible] except on four dates, when Dr. BECKER observed alone.

The several zones were, in general, about an hour long, and their complete observation, together with that of the instrumental constants and the determining-stars, occupied about three hours. On many nights, two zones were observed, and in some cases three. The average number of stars in each zone published in vol. IV was 52; that in those here published was 47; and that for the whole series was 49½. The magnitudes were, for the most part, taken directly from the *Durchmusterung*, instead of being estimated by the observer; but whenever a marked difference from the DM. was noted, the fact was recorded.

Tables, appended to the Introduction, contain, for the entire series of zones: 1) errors found in the magnitudes; 2) other errors detected in the observations, or results, as printed; and 3) corrections to the Introduction, the Standard Stars, Tables, etc.

Vol. VI of the same Annals contains reductions of former observations, carried out in a manner worthy of their authorship. It begins with an extended and elaborate investigation of the various errors of the Leiden meridian-circle, before it was refitted in 1876, which affect the determination of zenith-distances. This portion, which is as full of interest in its discussion of methods as in their practical application, is followed by reductions of long series of observations published in former volumes.

Pages 1 to 277 contain a large number of determinations of the zenith distances of 166 fundamental stars, observed between 1864 Feb. 13 and 1868 July 1. Among these stars are *α Lyrae* and 61(1) *Cygni*, for which the reductions for parallax are included. On pages 279 to 389 are the reductions and resultant values for the four polar stars, *α*, *δ* and *λ Ursae minoris* and 51(*Hev.*) *Cephei*. Finally, on pages 391 to 412, are analogous new reductions for 116 stars, not belonging to the fundamental list, which were observed between 1867 Sept. 17 and 1879 March 11 for use in the geodetic survey, and were published in a less complete form in vol. II, p. [37] of the Leiden Annals.

Publications of the Leander McCormick Observatory of the University of Virginia. Ormond Stone, *Director*. Vol. I, Part 5. *Durchmusterung*, —23°.

This work is in continuation of the *Durchmusterung* by Argelander and Schönfeld, and comprises the degree of declination from —23° 0′ to —24° 0′ for the mean equinox of 1855.0; the total number of stars being 6671, only 98 of which fall north of the limits, and 55 south of it.

The observations were made at the Cincinnati Observatory, under the direction of Prof. Stone, by himself and his assistants, Messrs. F. P. Leavenworth, H. C. Wilson, H. V. Egbert, and John Jones, using equatorial telescopes of 4 inches aperture, for both the original observations and the revision. These were used with a magnifying power of 15, and were equipped with a scale of plane glass, divided into 5′ spaces, by which the differential declinations were estimated, while the edge of the glass served for chronographic observation of the transits. The magnitudes of the stars were estimated to tenths.

For the reductions, each zone was compared with the positions in Oeltzen's Argelander, after referring these to the epoch 1855.0. Tables were deduced from this comparison, giving the corrections to be applied to the observed places, and having for arguments the time as taken from the chronograph and the scale-reading. The magnitudes were referred to Argelander's scale by tables, also constructed for each zone.

The resultant catalogue contains the magnitudes, right-ascensions and declination with the same degree of approximation as that of the Bonn *Durchmusterung*; and in the column of References those stars are identified, which occur in the Cordoba Zone-Catalogue, the Argentine General Catalogue, Oeltzen's reduction of Argelander's Zones, and the Washington Zones.

It is printed in large octavo, and is very conveniently arranged for reference, one hundred stars being given on each page.

The Solar Parallax and its Related Constants, including the Figure and Density of the Earth. By William Harkness, *Professor of Mathematics, U.S. Navy.* Washington Observations for 1885. — Appendix III. 1891.

The fundamental idea of this elaborate work, to which Prof. Harkness has devoted his energies for several years, is that,— since a large number of the astronomical, physical and geodetic constants are intimately related, — more trustworthy values for all of them can be attained by the solution of equations of condition, in which the best values resulting from observation are introduced and combined with the expression of their mutual relations.

Consequently, he has collected the various determinations of each of the constants in question, decided upon the values to be adopted in the computations, often using the method of least squares for this purpose; and has then employed this method in order to obtain a resultant homogeneous system.

In this way he deduces values for the dimensions and figure of the Earth, the length of the seconds-pendulum, the constant of solar attraction, the eccentricity of the earth's orbit, the length of the sidereal and tropical years, the moon's mean motion, the masses of Earth and Moon, the mean and surface-density of the Earth, the lunar inequality, the constants of precession, nutation and aberration, the planetary masses, solar and lunar parallaxes, velocity of light, etc.

The probable corrections, to be applied to all these constants in order to make up a homogeneous and accordant system, are determined by a series of adjustments, and probable errors are deduced for the resultant qualities. Among Prof. Harkness's results are the following: —

Earth's equatorial semidiameter,	6 377 972 ± 124.8 meters
Earth's polar "	6 356 727 ± 99.1 "
Length of seconds-pendulum,	$0^{m}.990\,91 + 0^{m}.005\,29 \sin^2 \varphi$
Length of sidereal day,	86 164.099 65 mean solar seconds
Length of sidereal year,	$365^{d}\ 6^{h}\ 9^{m}\ 9^{s}.314$
Solar parallax,	8″.809 05 ± 0″.005 67
Lunar parallax,	3 422″.542 16 ± 0″.125 33
Constant of aberration,	20″.454 51 ± 0″.012 58

A catalogue is given of 373 works which have been consulted in the prosecution of the investigation.

CORRIGENDUM.

No. 239, p. 182, col. 1, line 12. Supply the factor $\sec\delta$ in second term.

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Elements of Comet *a* 1891, by Mr. William Bellamy.
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Mr. Berberich of the *Berliner Jahrbuch* has announced that the asteroid discovered by Charlois Feb. 11 (*A.J.* 167) is identical with no. 208, *Lacrimosa*, the opposition of which, given in the *Jahrbuch* for 1893, had been computed with erroneous elements.

The numbers of the last three announced on p. 167 will consequently remain as there given (See *A.J.* p. 176). Those of March 1 and 5 thus become 306 and 307, respectively; that of March 31 (p. 184), 308; and that of April 6 (p. 191) becomes 309. These changes have been made in this Index.

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